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Contents

Glossary

This glossary is compiled according to the Lead Authors of the Report drawing on glossaries and other resources available on the websites of the following organizations, networks and projects: Intergovernmental Panel on Climate Change, Non-State Actor Zone for Climate Action, United Nations Environment Programme, United Nations Framework Convention on Climate Change and World Resources Institute.

Baseline/reference: The state against which change is measured. In the context of transformation pathways, the term ‘baseline scenarios’ refers to scenarios that are based on the assumption that no mitigation policies or measures will be implemented beyond those that are already in force and/or are legislated or planned to be adopted. Baseline scenarios are not intended to be predictions of the future, but rather counterfactual constructions that can serve to highlight the level of emissions that would occur without further policy effort. Typically, baseline scenarios are then compared to mitigation scenarios that are constructed to meet different goals for greenhouse gas emissions, atmospheric concentrations or temperature change. The term ‘baseline scenario’ is used interchangeably with ‘reference scenario’ and ‘no policy scenario’. In much of the literature the term is also synonymous with the term ‘business as usual (BAU) scenario’, although the term ‘BAU’ has fallen out of favour because the idea of ‘business as usual’ in century-long socioeconomic projections is hard to fathom.

Bioenergy: Energy derived from any form of biomass such as recently living organisms or their metabolic by-products

Black carbon: The substance formed through the incomplete combustion of fossil fuels, biofuels, and biomass, which is emitted in both anthropogenic and naturally occurring soot. It consists of pure carbon in several linked forms. Black carbon warms the Earth by absorbing heat in the atmosphere and by reducing albedo – the ability to reflect sunlight – when deposited on snow and ice.

Cancun pledge: During 2010, many countries submitted their existing plans for controlling greenhouse gas emissions to the Climate Change Secretariat and these proposals were formally acknowledged under the United Nations Framework Convention on Climate Change (UNFCCC). Developed countries presented their plans in the shape of economy-wide targets to reduce emissions, mainly up to 2020, while developing countries proposed ways to limit their growth of emissions in the shape of plans of action.

Carbon dioxide emission budget (or carbon budget): For a given temperature rise limit, for example a 1.5°C or 2°C long-term limit, the corresponding carbon budget reflects the total amount of carbon emissions that can be emitted for temperatures to stay below that limit. Stated differently, a carbon budget is the area under a carbon dioxide (CO_2) emission trajectory that satisfies assumptions about limits on cumulative emissions estimated to avoid a certain level of global mean surface temperature rise.

Carbon dioxide equivalent (CO_2e): A way to place emissions of various radiative forcing agents on a common footing by accounting for their effect on climate. It describes, for a given mixture and amount of greenhouse gases, the amount of CO_2 that would have the same global warming ability, when measured over a specified time period. For the purpose of this report, greenhouse gas emissions (unless otherwise specified) are the sum of the basket of greenhouse gases listed in Annex A to the Kyoto Protocol, expressed as CO_2e assuming a 100-year global warming potential.

Carbon intensity: The amount of emissions of CO_2 released per unit of another variable such as gross domestic product, output energy use, transport or agricultural/forestry products.

Carbon offset: *See Offset.*

Carbon price: The price for avoided or released CO_2 or CO_2e emissions. This may refer to the rate of a carbon tax or the price of emission permits. In many models that are used to assess the economic costs of mitigation, carbon prices are used as a proxy to represent the level of effort in mitigation policies.

Carbon tax: A levy on the carbon content of fossil fuels. Because virtually all of the carbon in fossil fuels is ultimately emitted as CO_2, a carbon tax is equivalent to an emission tax on CO_2 emissions.

Co-benefits: The positive effects that a policy or measure aimed at one objective might have on other objectives, without yet evaluating the net effect on overall social welfare. Co-benefits are often subject to uncertainty and depend on, among others, local circumstances and implementation practices. Co-benefits are often referred to as ancillary benefits.

Conditional NDC: NDC proposed by some countries that are contingent on a range of possible conditions, such as the ability of national legislatures to enact the necessary laws, ambitious action from other countries, realization of finance and technical support, or other factors.

Conference of the Parties (COP): The supreme body of the United Nations Framework Convention on Climate Change. It currently meets once a year to review the Convention's progress.

Crowding in: The mobilization of private sector finance for innovative investment projects through public sector (co-)financing of these investments

Current policy trajectory: This trajectory is based on estimates of 2020 emissions considering projected economic trends and current policy approaches including policies at least through 2015. Estimates may be based on either official data or independent analysis.

Deforestation: Conversion of forest to non-forest.

Economic mitigation potential: The mitigation potential, which takes into account social costs and benefits and social discount rates, assuming that market efficiency is improved by policies and measures and barriers are removed

Effective carbon rate: Is the sum of carbon prices and excise taxes per unit of carbon contained in a specific fossil fuel.

Emissions gap: The difference between the greenhouse gas emission levels consistent with a specific probability of limiting the mean global temperature rise to below 2°C or 1.5°C in 2100 above pre-industrial levels and the GHG emission levels consistent with the global effect of the NDCs, assuming full implementation from 2020.

Emission pathway: The trajectory of annual greenhouse gas emissions over time.

Excise tax: A tax on the consumption or use of a specific good, service, or activity. Excise taxes are mainly introduced with the intention to create public revenues for local, state or federal governments. Common examples for excise taxes are taxes on alcohol, tobacco, or fuel.

Global warming potential: An index representing the combined effect of the differing times greenhouse gases remain in the atmosphere and their relative effectiveness in absorbing outgoing infrared radiation.

Green fiscal reform: A major change in the tax system with the intention of introducing or increasing taxes on environmental bads (such as pollution, carbon emissions) while simultaneously decreasing other taxes (such as income taxes).

Greenhouse gases: The atmospheric gases responsible for causing global warming and climatic change. The major greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Less prevalent, but very powerful, GHGs are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

Innovation landscape: The entirety of the activities of innovation from research and development to diffusion of competitive products

Integrated assessment models: Models that seek to combine knowledge from multiple disciplines in the form of equations and/or algorithms in order to explore complex environmental problems. As such, they describe the full chain of climate change, from production of greenhouse gases to atmospheric responses. This necessarily includes relevant links and feedbacks between socio-economic and biophysical processes.

Intended Nationally Determined Contribution (INDC): INDCs are submissions from countries describing the national actions it intends to take to reach the Paris Agreement's long-term temperature goal of limiting warming to well below 2°C. Once a country has ratified the Paris Agreement, its INDC is automatically converted to its NDC (see below), unless it chooses to further update it. INDCs are thus only used in this publication in reference to countries that have not yet ratified the Paris Agreement.

Kigali Amendment: The Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer aims for the phase-down of hydrofluorocarbons (HFCs) by cutting their production and consumption.

Kyoto Protocol: An international agreement, standing on its own, and requiring separate ratification by governments, but linked to the UNFCCC. The Kyoto Protocol, among other things, sets binding targets for the reduction of greenhouse gas emissions by industrialized countries.

Land use, land-use change and forestry (LULUCF): A greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use, land use change and forestry activities.

Likely chance: A likelihood greater than 66 percent chance. Used in this assessment to convey the probabilities of meeting temperature limits.

Lock-in: Lock-in occurs when a market is stuck with a standard even though participants would be better off with an alternative.

Mitigation: In the context of climate change, a human intervention to reduce the sources, or enhance the sinks of greenhouse gases. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings and expanding forests and other 'sinks' to remove greater amounts of CO_2 from the atmosphere.

Monitoring, reporting and verification: A process/concept that potentially supports greater transparency in the climate change regime.

Nationally Determined Contribution (NDC): Submissions by countries that have ratified the Paris Agreement which presents their national efforts to reach the Paris Agreement's long-term temperature goal of limiting warming to well below 2°C. New or updated NDCs are to be submitted in 2020 and every five years thereafter. NDCs thus represent a country's current ambition/target for reducing emissions nationally.

Non-state and subnational actors: 'Non-state and subnational actors' includes companies, cities, subnational regions and investors that take or commit to climate action.

Offset (in climate policy): A unit of CO_2e emissions that is reduced, avoided, or sequestered to compensate for emissions occurring elsewhere.

Scenario: A description of how the future may unfold based on 'if-then' propositions. Scenarios typically include an initial socio-economic situation and a description of the key driving forces and future changes in emissions, temperature or other climate change-related variables.

Source: Any process, activity or mechanism that releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol into the atmosphere.

Sustainable development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Technical mitigation potential: Such potential is estimated for given scenarios assuming full implementation of best available pollutant reduction technology, as it exists today, by 2030 independent of their costs but considering technical lifetime of technologies and other key constraints (e.g., cultural acceptance) that could limit applicability of certain measures in specific regions.

Uncertainty: A cognitive state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (for example a probability density function) or by qualitative statements (for example reflecting the judgement of a team of experts).

Unconditional NDCs: NDCs proposed by countries without conditions attached.

2020 pledge: *See Cancun pledge.*

Acronyms

°C	Degree Celsius
CDR	Carbon Dioxide Removal
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COP	Conference of the Parties to the UNFCCC
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicle
G20	Group of twenty
GHG	Greenhouse Gas
Gt	Gigaton
GW	Gigawatt
ICI	International Cooperative Initiative
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
LUC	Land Use Change
LULUCF	Land use, land-use change and forestry
m^2	Square metre
Mt	Million metric ton
NDC	Nationally Determined Contribution
NSA	Non-state and Subnational Actor
OECD	Organisation for Economic Cooperation and Development
PV	Solar Photovoltaic
R&D	Research and Development
SIB	State Investment Bank
tCO_2	Metric ton of CO_2
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America

Foreword

The world is at last beginning to tackle its fossil fuel addiction. Coal is no longer competitive, and wind farms and solar installations are gathering pace – in Australia, northern Europe, China, India and elsewhere. Electric mobility and ride sharing are redefining transport, especially in cities tired of breathing dirty air. Huge strides in energy efficiency are being made.

The problem, as the science here is telling us, is that we're not making the change nearly as quickly as we need to. This is of course not new – it's an almost carbon copy of what we were told last year, and the years before that. But what we do have is yet more compelling science, and something that adds to that provided by the 1.5 degree report recently released by the Intergovernmental Panel on Climate Change.

The message is clear: we need to make an almost existential change, the solutions are there, and we have no excuse.

And yes, it is still possible to bridge the emissions gap to keep global warming below 2°C. However, the opportunity to bridge the 1.5°C gap is dwindling. We can also see that the kind of unprecedented action we urgently need is not happening yet: in fact, global CO_2 emissions did increase in 2017 after a few years of stagnation.

Even if the nations of the world live up to their current commitments, that will likely result in global warming of around 3°C by the end of the century. That's a number that would be catastrophic – and fatal for many small island states and coastal areas. The fact is that we are already seeing climate change play out in front of us. From the Caribbean superstorms to droughts in the Horn of Africa, or record temperatures and wildfires, our planet is already changing.

Closing the Emissions Gap means upping our ambition. Net zero must become the new mantra, and we must pursue this goal with confidence. After all, the science and data also show us that reducing and offsetting emissions does not mean cutting growth. Quite the contrary.

The science also shows emission reduction potential from other actors such as regional and local governments and businesses – is very large. That means that initiatives like the C40 cities coalition must be commended and supported. So too must action to improve air quality in cities – a double win that spares both children from the trauma of asthma and tackles some of the root causes of other emissions.

Current impacts of actions by other actors are still limited and not well enough documented, but we need to look for action in all corners of the modern world.

We can also see that fiscal policies provide a huge opportunity to reduce future emissions but need to be designed and implemented carefully to deliver desired results without creating economic and social issues. The space for policies to boost innovation and open new markets for emerging technologies and practices also has significant mitigation potential.

The key is to understand we are not powerless in the face of climate change. The science may be frightening, but the solutions are clear. The only missing link is leadership.

Joyce Msuya

Acting Executive Director
United Nations Environment Programme

Executive summary

This is the 9th edition of the UN Environment Emissions Gap Report. It assesses the latest scientific studies on current and estimated future greenhouse gas emissions and compares these with the emission levels permissible for the world to progress on a least-cost pathway to achieve the goals of the Paris Agreement. This difference between "where we are likely to be and where we need to be" is known as the 'emissions gap'. As in previous years, the report explores some of the most important options available for countries to bridge the gap.

The political context this year is provided by several processes and events:

- The Talanoa Dialogue – an inclusive, participatory and transparent dialogue about ambitions and actions, conducted under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC) and designed to help build momentum for new or updated Nationally Determined Contributions (NDCs) to be submitted by 2020.
- The Global Climate Action Summit in September 2018 – bringing together many non-state and subnational actors (NSAs) that are actively involved in climate issues.
- The Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C – focusing on "the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty". The Emissions Gap Report has benefited significantly from the IPCC Special Report and its underlying studies.

This Emissions Gap Report has been prepared by an international team of leading scientists, assessing all available information, including that published in the context of the IPCC Special Report, as well as in other recent scientific studies. The assessment production process has been transparent and participatory. The assessment methodology and preliminary findings were made available to the governments of the countries specifically mentioned in the report to provide them with the opportunity to comment on the findings.

1. **Current commitments expressed in the NDCs are inadequate to bridge the emissions gap in 2030. Technically, it is still possible to bridge the gap to ensure global warming stays well below 2°C and 1.5°C, but if NDC ambitions are not increased before 2030, exceeding the 1.5°C goal can no longer be avoided. Now more than ever, unprecedented and urgent action is required by all nations. The assessment of actions by the G20 countries indicates that this is yet to happen; in fact, global CO_2 emissions increased in 2017 after three years of stagnation.**

This year's report presents the newest assessment of the emissions gap in 2030 between emission levels under full implementation of the unconditional and conditional NDCs and those consistent with least-cost pathways to stay below 2°C and 1.5°C respectively.

- With the results of the new global studies prepared for the IPCC report, the emissions gap – especially to stay below 1.5°C warming – has increased significantly in comparison with previous estimates, as new studies explore more variations and make more cautious assumptions about the possibility of global carbon dioxide-removal deployment.
- Pathways reflecting current NDCs imply global warming of about 3°C by 2100, with warming continuing afterwards. If the emissions gap is not closed by 2030, it is very plausible that the goal of a well-below 2°C temperature increase is also out of reach.

- The assessment of country action for this Emissions Gap Report concludes that while most G20 countries are on track to meet their Cancun pledges for 2020, the majority are not yet on a path that will lead them to fulfilling their NDCs for 2030.
- Concerns about the current level of both ambition and action are thus amplified compared to previous Emissions Gap Reports. According to the current policy and NDC scenarios, global emissions are not estimated to peak by 2030, let alone by 2020. The current NDCs are estimated to lower global emissions in 2030 by up to 6 $GtCO_2e$ compared to a continuation of current policies. As the emissions gap assessment shows, this original level of ambition needs to be roughly tripled for the 2°C scenario and increased around fivefold for the 1.5°C scenario.
- Action by non-state and subnational actors (NSAs), including regional and local governments and businesses, is key to implementing the NDCs. The strong engagement by NSAs demonstrated at the recent Global Climate Action Summit is promising and can help governments deliver on their NDCs, but the impact of current individual NSA pledges on reducing the gap is extremely limited. Chapter 5 of this Emissions Gap Report was pre-released at the Summit, and documents that if international cooperative initiatives succeed in increasing their membership and ambition, substantially greater potential can be realized. The chapter emphasizes that enhanced monitoring and reporting of actions and resulting emissions reductions will be essential for the credibility of NSA action.
- Countries therefore need to move rapidly on the implementation of their current NDCs; at the same time, more ambitious NDCs are necessary by 2020 to meet the jointly agreed goals. This report summarizes the different approaches countries can take to build enhanced ambition and enhance the scale, scope and effectiveness of their domestic policy.
- The policies and measures chapters in this year's report address two key aspects for the longer-term transition to a zero-emission economy and society. Fiscal policies provide a key opportunity for reducing future emissions, and there are options to design them in such a way that they deliver the desired results without creating economic and social problems. Several countries have demonstrated that it is possible to overcome social resistance, but few have gone far enough to have the necessary emissions reduction impact. Innovation policy and market creation also offer significant mitigation potential and governments should play a key role in ensuring the development and market introduction of new and emerging low-carbon technologies and practices.

The key messages from the 2018 Emissions Gap Report send strong signals to national governments and to the political part of the Talanoa Dialogue at the 24th session of the Conference of the Parties (COP 24). Along with the recent IPCC Special Report, these messages provide the scientific underpinning for the UN 2019 Climate Summit, which will convene on the theme of 'A Race We Can Win. A Race We Must Win'. By way of the summit, the United Nations Secretary-General will seek to challenge States, regions, cities, companies, investors and citizens to step up action in six key areas: energy transition, climate finance and carbon pricing, industry transition, nature-based solutions, cities and local action, and resilience.

2. **Global greenhouse gas emissions show no signs of peaking. Global CO_2 emissions from energy and industry increased in 2017, following a three-year period of stabilization. Total annual greenhouse gases emissions, including from land-use change, reached a record high of 53.5 $GtCO_2e$ in 2017, an increase of 0.7 $GtCO_2e$ compared with 2016. In contrast, global GHG emissions in 2030 need to be approximately 25 percent and 55 percent lower than in 2017 to put the world on a least-cost pathway to limiting global warming to 2°C and 1.5°C respectively.**

In 2017 greenhouse gas (GHG) emissions - excluding emissions from land-use change - reached a record 49.2 $GtCO_2e$. This is an increase of 1.1 percent on the previous year. Emissions from land-use change, which vary from year to year because of weather conditions, added another 4.2 $GtCO_2$, bringing the total to 53.5 $GtCO_2e$.

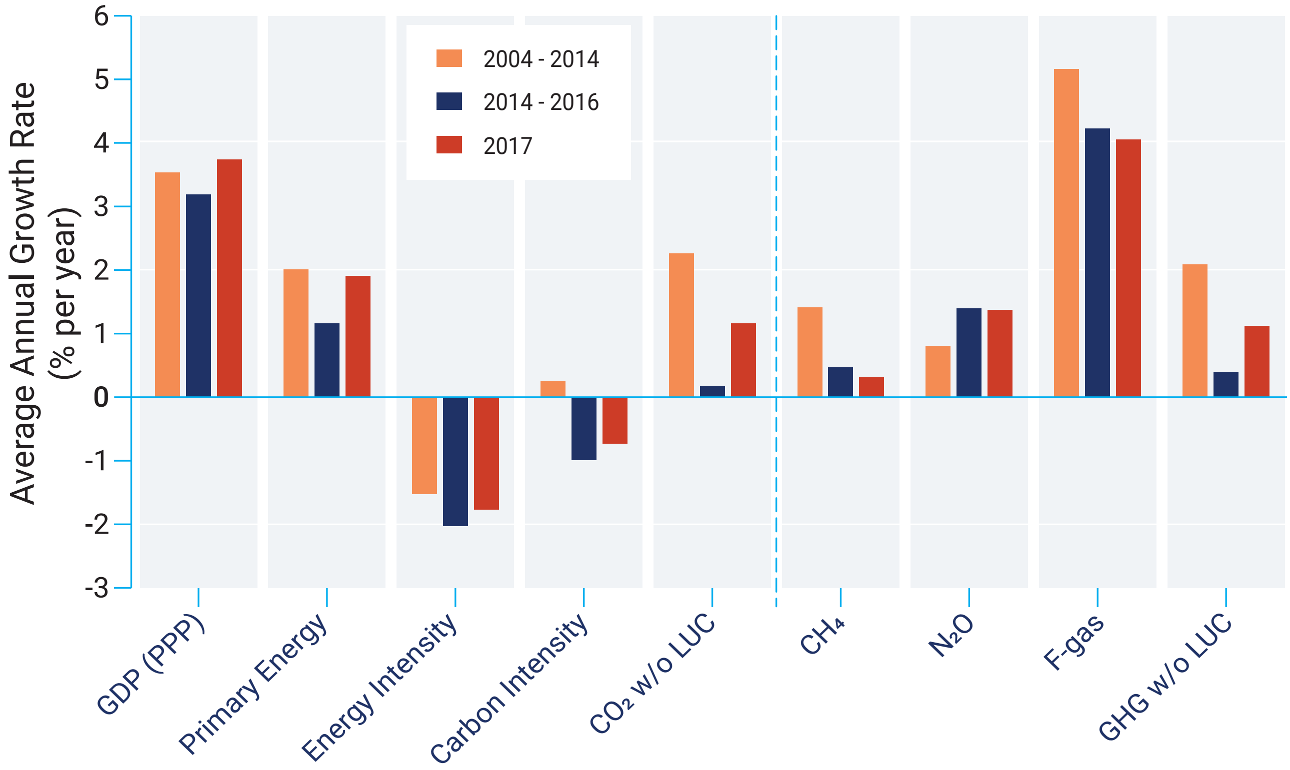
Despite modest growth in the world economy, CO_2 emissions from fossil fuel combustion, cement production and other industrial processes remained relatively stable from 2014 to 2016. This brought optimism to climate policy discussions, indicating that global GHG emissions might show signs of peaking. However, preliminary estimates of global CO_2 emissions from fossil fuels, industry and cement for 2017 suggest an increase of 1.2 percent (figure ES.1). The main drivers of the increase are higher gross domestic product (GDP) growth (about 3.7 percent) and slower declines in energy, and especially carbon, intensity, compared with the 2014–2016 period. The 2017 increase leaves considerable uncertainty as to whether the 2014–2016 slowdown was driven primarily by short-term economic factors.

Since CO_2 emissions from fossil fuels, industry and cement dominate total GHG emissions, the changes in CO_2 emissions had the largest influence on GHG emissions from 2014 to 2017. Land-use change emissions have remained relatively flat, despite large annual variations driven by weather patterns and uncertainty in input data.

Global peaking of emissions by 2020 is crucial for achieving the temperature targets of the Paris Agreement, but the scale and pace of current mitigation action remains insufficient. Following on from the Talanoa Dialogue, which has raised confidence in implementation efforts and has shown that increased ambition is possible, national governments have the opportunity to strengthen their current policies and their NDCs by 2020.

Global peaking of GHG emissions is determined by the aggregate emissions from all countries. While there has been steady progress in the number of countries that

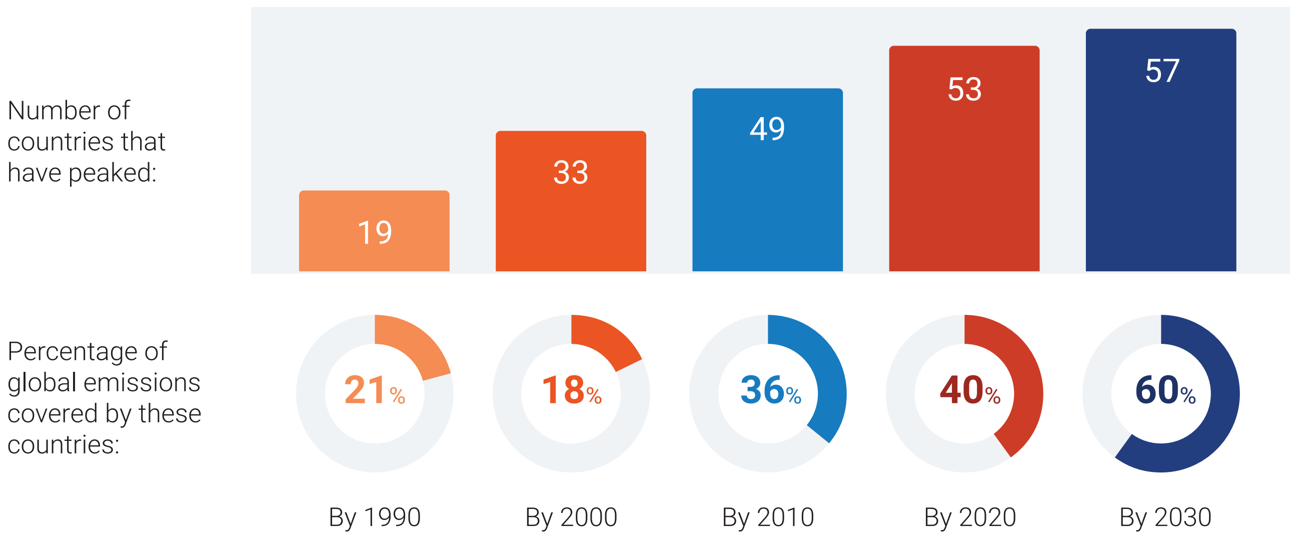
Figure ES.1: Average annual growth rates of key drivers of global CO_2 emissions (left of dotted line) and components of GHG emissions (right of dotted line).



Note: Land-use change emissions are not included due to large inter-annual variability. Leap-year adjustments are not included in the growth rates.

have peaked their GHG emissions or have pledged to do so in the future (figure ES.2), the 49 countries that have so far done so, and the 36 percent share of global emissions they represent, is not large enough to enable the world's emissions to peak in the near term. By 2030, up to 57 countries, representing 60 percent of global emissions, will have peaked, if commitments are fulfilled.

Figure ES.2: Number of countries that have peaked or are committed to peaking their emissions, by decade (aggregate) and percentage of global emissions covered (aggregate).



Source: Levin and Rich (2017).

Countries that have already peaked have a critical role to play in determining the timing and level of global emissions peaking, as each country's decarbonization rate after peaking will be a defining factor in global cumulative emissions. However, it is clear that countries that have peaked their GHG emissions have not reduced their emissions at a fast-enough rate since the peak year.

Collectively, G20 members are projected to achieve the Cancun pledges by 2020, but they are not yet on track to realize their NDCs for 2030. Consistent with past Emissions Gap Reports, this report finds that the GHG emissions of the G20 countries, as a group, will not have peaked by 2030 unless there is a rapid increase in ambition and action within the next few years.

While G20 members collectively are on track to achieving the target emission levels in 2020 implied by the Cancun pledges, some countries (Canada, Indonesia, Mexico, the Republic of Korea, South Africa and the USA) are either not projected to achieve their Cancun pledges, or there is uncertainty on whether they will achieve them.

At present, the G20 countries are collectively not on track to meet their unconditional NDCs for 2030. Around half of the G20 members' GHG emissions trajectories fall short of achieving their unconditional NDCs (Argentina, Australia, Canada, EU28, the Republic of Korea, Saudi Arabia, South Africa and the USA). Three G20 members (Brazil, China and Japan) are on track to meeting their NDC targets under current policies, while emissions under current policies of three additional countries (India, Russia and Turkey) are projected to be more than 10 percent below their unconditional NDC targets. This may, in some cases, reflect relatively low ambition in the NDCs. It is uncertain whether two countries (Indonesia and Mexico) are on track to meeting their NDC targets in 2030 under current policies.

G20 members will need to implement additional policies to reduce their annual GHG emissions further by about 2.5 $GtCO_2e$ to achieve their unconditional NDCs and by about 3.5 $GtCO_2e$ to achieve their conditional NDCs by 2030. These additional reductions needed have gone down by approximately 1 $GtCO_2e$ compared with 2017, due to lower projections of emissions under current policies in China, the EU28 and the USA.

Table ES.1: Total global greenhouse gas emissions in 2030 under different scenarios (median and 10th to 90th percentile range), temperature implications and the resulting emissions gap.

Scenario (rounded to the nearest gigatonne)	Number of scenarios in set	Global total emissions in 2030 [$GtCO_2e$]	Estimated temperature outcomes			Emissions Gap in 2030 [$GtCO_2e$]		
			50% chance	66% chance	90% chance	Below 2°C	Below 1.8°C	Below 1.5°C in 2100
No-policy baseline	179	65 (60–70)						
Current policy	4	59 (56–60)				18 (16–20)	24 (22–25)	35 (32–36)
Unconditional NDCs	12	56 (52–58)				15 (12–17)	21 (17–23)	32 (28–34)
Conditional NDCs	10	53 (49–55)				13 (9–15)	19 (15–20)	29 (26–31)
Below 2.0°C (66% chance)	29	40 (38–45)	Peak: 1.7–1.8°C In 2100: 1.6–1.7°C	**Peak: 1.9–2.0°C** **In 2100: 1.8–1.9°C**	Peak: 2.4–2.6°C In 2100: 2.3–2.5°C			
Below 1.8°C (66% chance)	43	34 (30–40)	Peak: 1.6–1.7°C In 2100: 1.3–1.6°C	**Peak: 1.7–1.8°C** **In 2100: 1.5–1.7°C**	Peak: 2.1–2.3°C In 2100: 1.9–2.2°C			
Below 1.5°C in 2100 (66% chance)	13	24 (22–30)	Peak: 1.5–1.6°C In 2100: 1.2–1.3°C	**Peak: 1.6–1.7°C** **In 2100: 1.4–1.5°C**	Peak: 2.0–2.1°C In 2100: 1.8–1.9°C			

Note: The gap numbers and ranges are calculated based on the original numbers (without rounding), which may differ from the rounded numbers (third column) in the table. Numbers are rounded to full $GtCO_2e$. GHG emissions have been aggregated with 100-year global warming potential (GWP) values of the IPCC Second Assessment Report. The NDC and current policy emission projections may differ slightly from the presented numbers in Cross-Chapter Box 11 of the IPCC Special Report (Bertoldi *et al.*, 2018) due to the inclusion of new studies after the literature cut-off date set by the IPCC. Pathways were grouped in three categories depending on whether their maximum cumulative CO_2 emissions were less than 600 $GtCO_2$, between 600 and 900 $GtCO_2$, or between 900 and 1,300 $GtCO_2$ from 2018 onwards until net zero CO_2 emissions are reached, or until the end of the century if net zero is not reached before. Pathways assume limited action until 2020 and cost-optimal mitigation thereafter. Estimated temperature outcomes are based on the method used in the IPCC 5th Assessment Report.

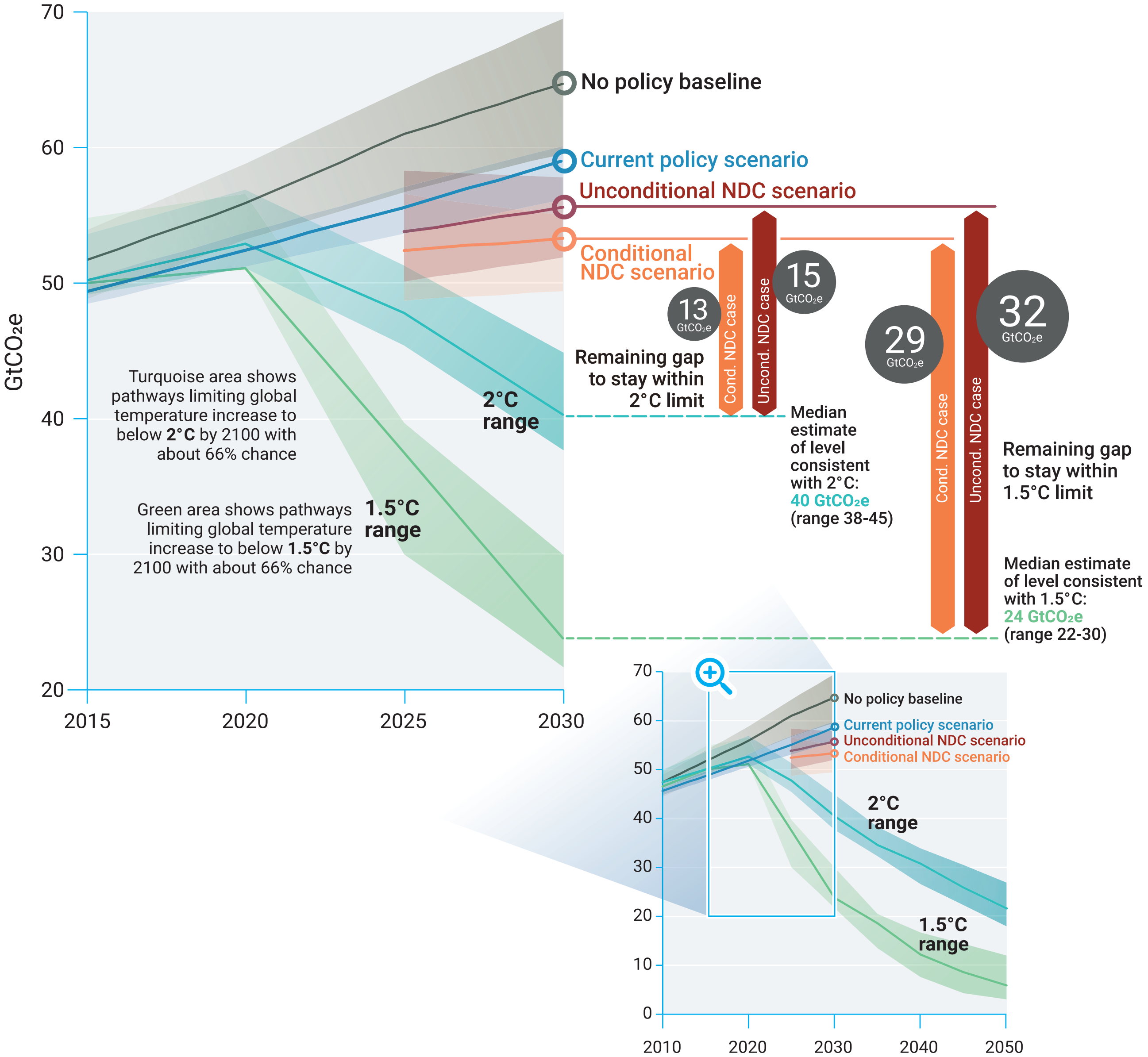
3. The gap in 2030 between emission levels under full implementation of conditional NDCs and those consistent with least-cost pathways to the 2°C target is 13 $GtCO_2e$. If only the unconditional NDCs are implemented, the gap increases to 15 $GtCO_2e$. The gap in the case of the 1.5°C target is 29 $GtCO_2e$ and 32 $GtCO_2e$ respectively. This gap has increased compared with 2017 as a result of the expanded and more diverse literature on 1.5°C and 2°C pathways prepared for the IPCC Special Report.

The 2018 Emissions Gap Report draws on a substantial number of new, least-cost scenarios for meeting the 2°C and 1.5°C warming limits. Last year 16 scenarios were available for both the 1.5°C and 2°C pathway categories; this year, there are a total of 85. These new scenarios are more diverse and often set a lower maximum potential for carbon dioxide removal, which in turn results in deeper emissions reductions over the coming decades to stay within the same overall carbon budget. Each of the scenarios considers least-cost climate change mitigation pathways that start reductions from 2020 and is based on the climate model and set-up used in the IPCC 5th Assessment Report.

Three temperature levels – 2°C, 1.8°C and 1.5°C – are chosen to provide a more nuanced overview of pathways that keep warming in the range of 2°C to 1.5°C, including providing an overview of the peak and 2100 temperature outcomes associated with different likelihoods (table ES.1). The inclusion of the 1.8°C level allows a more nuanced interpretation and discussion of the Paris Agreement's temperature targets.

Current policies are estimated to reduce global emissions in 2030 by around 6 $GtCO_2e$ compared with

Figure ES.3: Global greenhouse gas emissions under different scenarios and the emissions gap in 2030 (median estimate and 10th to 90th percentile range).



the no-policy scenario (table ES.1). This is in line with the 2017 assessment, implying that studies have not identified significant and unambiguous progress in the implementation of policies that would enable the NDCs to be achieved by 2030.

The updates to this year's assessment result in changes of the GHG emission levels in 2030, compared with the 2017 Emissions Gap Report, consistent with limiting global warming to 2°C and lower. According to the new scenario estimates, emissions of all GHGs should not exceed 40 (range 38–45) $GtCO_2e$ in 2030, if the 2°C target is to be attained with about 66 percent chance. To keep global warming to 1.8°C with about 66 percent chance, global GHG emissions in 2030 should not exceed 34 (range 30–40) $GtCO_2e$. For a 66 percent chance of keeping temperature increase below 1.5°C in 2100 (associated with no or a low overshoot), global GHG emissions in 2030 should not exceed 24 (range 22–30) $GtCO_2e$.

The full implementation of the unconditional NDCs is estimated to result in a gap of 15 $GtCO_2e$ (range 12–17) in 2030 compared with the 2°C scenario. This is about 2 $GtCO_2e$ higher than the gap assessed in the previous report because the most recent 2°C scenarios indicate a lower benchmark. If, in addition, the conditional NDCs are fully implemented, the gap is reduced by about 2 $GtCO_2e$. The emissions gap between unconditional NDCs and 1.5°C pathways is about 32 $GtCO_2e$ (range 28–34). This is about 13 $GtCO_2e$ higher than the assessment in the 2017 report, due to the much larger number of available scenario studies that rely less on large volumes of carbon dioxide removal and thus show lower 2030 benchmark values. Considering the full implementation of both unconditional and conditional NDCs would reduce this gap by about 3 $GtCO_2e$.

Implementing unconditional NDCs, and assuming that climate action continues consistently throughout the 21st Century, would lead to a global mean temperature rise of about 3.2°C (with a range of 2.9–3.4°C) by 2100 relative to pre-industrial levels, and continuing thereafter. Implementation of the conditional NDCs would reduce these estimates by 0.2°C in 2100. These projections are similar to the 2017 estimates.

4. **Countries need to strengthen the ambition of NDCs and scale up and increase effectiveness of domestic policy to achieve the temperature goals of the Paris Agreement. To bridge the 2030 emissions gap and ensure long-term decarbonization consistent with the Paris Agreement goals, countries must enhance their mitigation ambition. Enhanced ambition in the NDCs sends an important signal regarding mitigation commitment, both internationally and domestically. However, domestic policies are crucial to translate mitigation ambition into action.**

Ambition can, in this context, be viewed as a combination of target-setting, preparedness to implement and a capacity to sustain further reductions over time.

There are various ways in which a country could reflect enhanced mitigation ambition in its NDCs (figure ES.4). These options are not mutually exclusive, and whether an NDC revision results in enhanced ambition depends on the scale of the revision rather than its form. It is important for countries to consider a wide range of options to identify those that are most meaningful and practical in their unique circumstances, and to bring about the deep emission reductions required to bridge the gap.

Major gaps in coverage and stringency of domestic policies remain, including among G20 members, in, for example, fossil fuel subsidy reduction, material efficiency measures in industry, oil and gas, methane, support schemes for renewables heating and cooling, emission standards for heavy-duty vehicles, and e-mobility programmes. Even in areas where policy coverage is high, stringency can be improved. For example, while all G20 countries have policies to support renewables in the electricity sector, stringency of these policies can still be enhanced.

The technical potential for reducing GHG emissions is significant and could be sufficient to bridge the emissions gap in 2030. A substantial part of this potential can be realized through scaling up and replicating existing, well-proven policies that simultaneously contribute to key sustainable development goals.

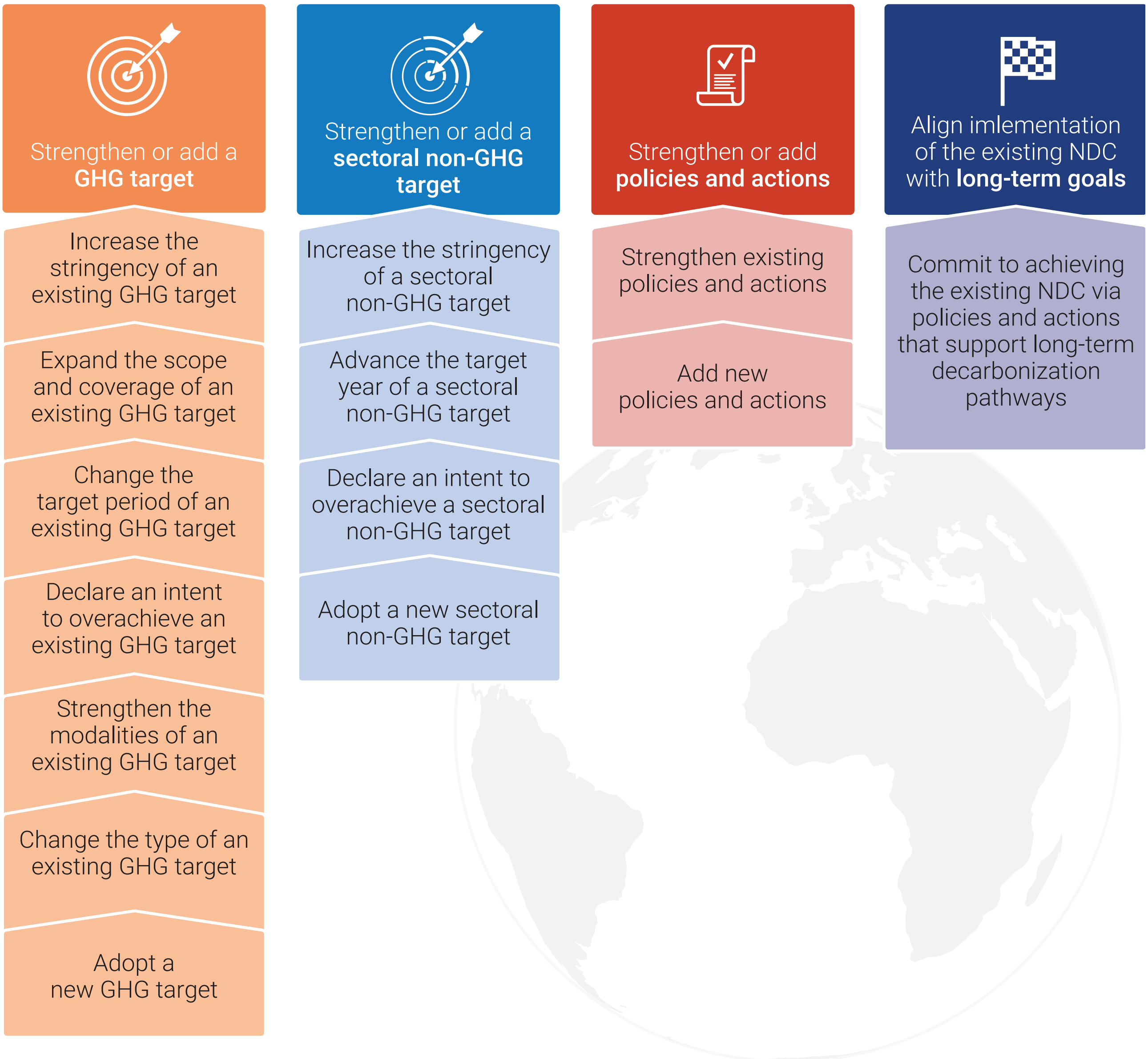
The 2017 Emissions Gap Report provided an updated assessment of the sectoral emission reduction potentials that are technically and economically feasible in 2030, considering prices up to US\$100/tCO_2e. It found that global emissions could be reduced by 33 (range 30–36) $GtCO_2e$/year in 2030, compared with the current policy scenario of 59 $GtCO_2e$/year (Chapter 3). If, in addition, a number of newer and less certain mitigation options were included, the mitigation potential would increase to 38 (range 35–41) $GtCO_2e$. The emissions reduction potential is thus sufficient to bridge the gap in 2030. As the 2017 Emissions Gap Report showed, a large part of the technical potential lies in three broad areas: renewable energy from wind and solar, energy-efficient appliances and cars, and afforestation and stopping deforestation.

In these and many other areas – and across all countries – there is significant potential to realize a substantive part of the technical mitigation potential through the replication of proven good-practice policies that can simultaneously contribute to key sustainable development goals. Realizing this potential would significantly narrow the gap by 2030, beyond current NDCs.

5. **Non-state and subnational action plays an important role in delivering national pledges. Emission reduction potential from non-state and subnational action could ultimately be significant, allowing countries to raise ambition, but the current impacts are extremely limited and poorly documented.**

NSAs provide important contributions to climate action beyond their quantified emission reductions. They build confidence in governments concerning climate policy and push for more ambitious national goals. They provide space for experimentation or act as

Figure ES.4: Typology of strengthening mitigation ambition of NDCs.



Source: adapted from Fransen *et al.* (2017).

orchestrators, coordinating with national governments on climate policy implementation. Initiatives and actors also incentivize, support and inspire additional climate action by exchanging knowledge and good practices, engaging in advocacy and policy dialogue, assisting in formulating action plans, and rewarding and recognizing climate actions.

The number of actors participating is rising fast: more than 7,000 cities from 133 countries and 245 regions from 42 countries, along with more than 6,000 companies with at least US$36 trillion in revenue, have pledged mitigation action. Commitments cover large parts of the economy and are gradually expanding in regional coverage. Many of the actors are engaging in so-called 'international cooperative initiatives', which are characterized by multi-country and multi-actor engagement.

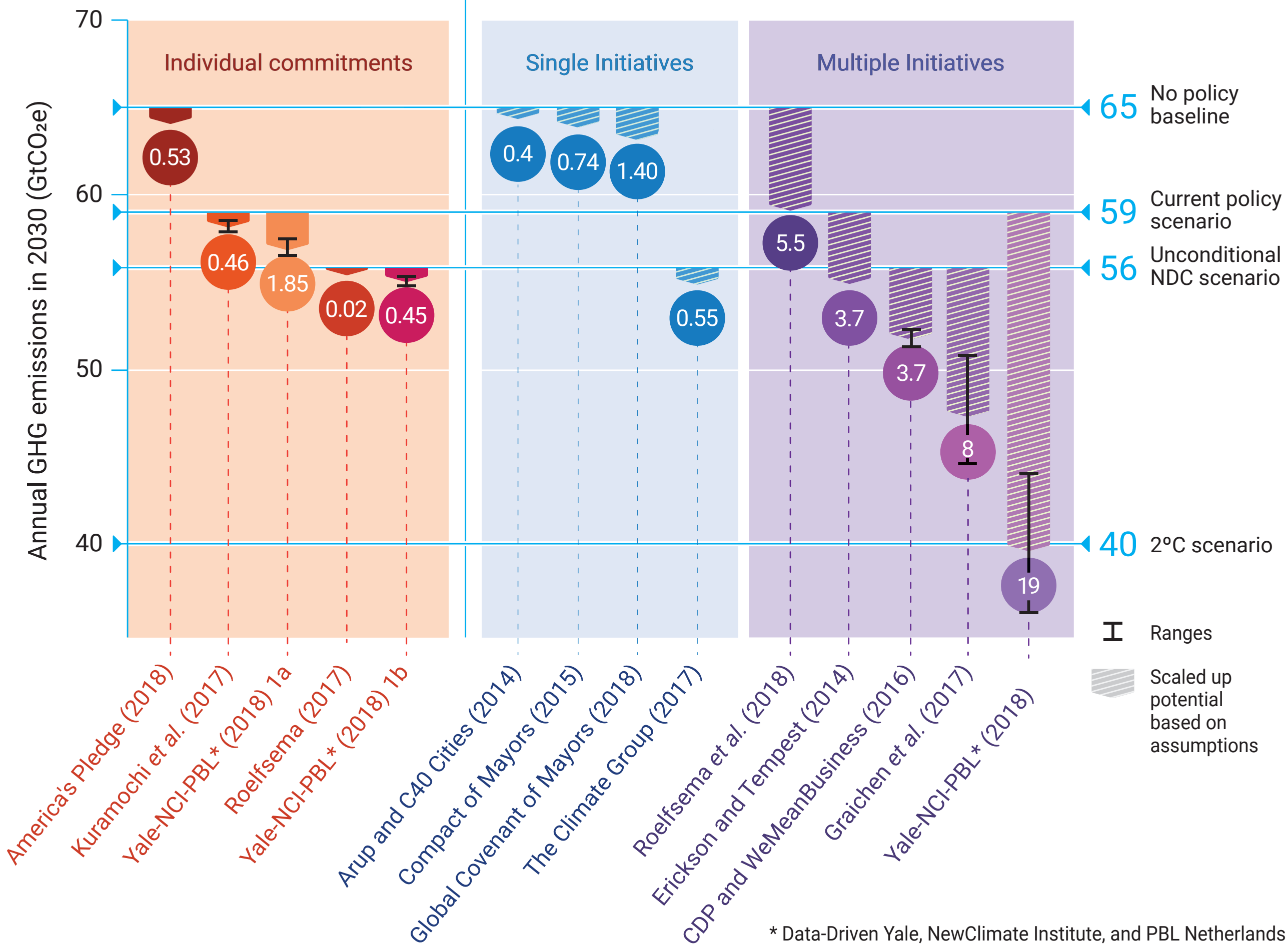
The numbers seem impressive, but there is still huge potential for expansion. Based on available data, not even 20 percent of the world population is represented in current national and international initiatives, and many more of the over 500,000 publicly traded companies worldwide still can, and must, act. On the financial side, a record of just over US$74 billion of Green Bonds were issued in the first half of 2018, but this still represents only a very small fraction of the capital markets around the world.

The emission reduction potential from NSAs is large, but estimates vary considerably across studies (figure ES.5). If international cooperative initiatives are scaled up to their fullest potential, the impact could be considerable compared with current policy: up to 19 $GtCO_2e$/year by 2030 (range 15–23 $GtCO_2e$) according to one study. If realized, this would be instrumental in bridging the emissions gap to 2°C pathways.

Figure ES.5: The range of estimated potential emission reductions in various NSA studies.

Figure ES.5a: Emission reduction potential of pledged commitments by NSAs.

Figure ES.5b: Scaled up potential emission reductions based on single and multiple initiatives.



Source: Based on data in table 5.2.

Note: a) For studies that include ranges, median estimates are provided with ranges indicated in figures ES.5a and ES.5b.
b) Studies that are cross-hatched evaluate single and multiple ICI goals rather than individual actors' recorded and quantified pledges. They rely on assumptions of future scaled-up impact and therefore represent potential rather than a quantified analysis of individual actors' NSA pledges.
c) Extrapolation of 2025 estimates has been made.

However, the additional emission reductions under full implementation of pledged commitments made so far by individual non-state actors are still quite limited: up to 0.45 $GtCO_2e$/year (range 0.2–0.7 $GtCO_2e$/year) by 2030 compared with full unconditional NDC implementation, and up to 1.85 $GtCO_2e$/year (range 1.5–2.2 $GtCO_2e$/year) compared with current policy. A more comprehensive assessment of all non-state and subnational climate action occurring globally is limited by the current low level of available data and lack of consistent reporting on non-state and subnational climate action.

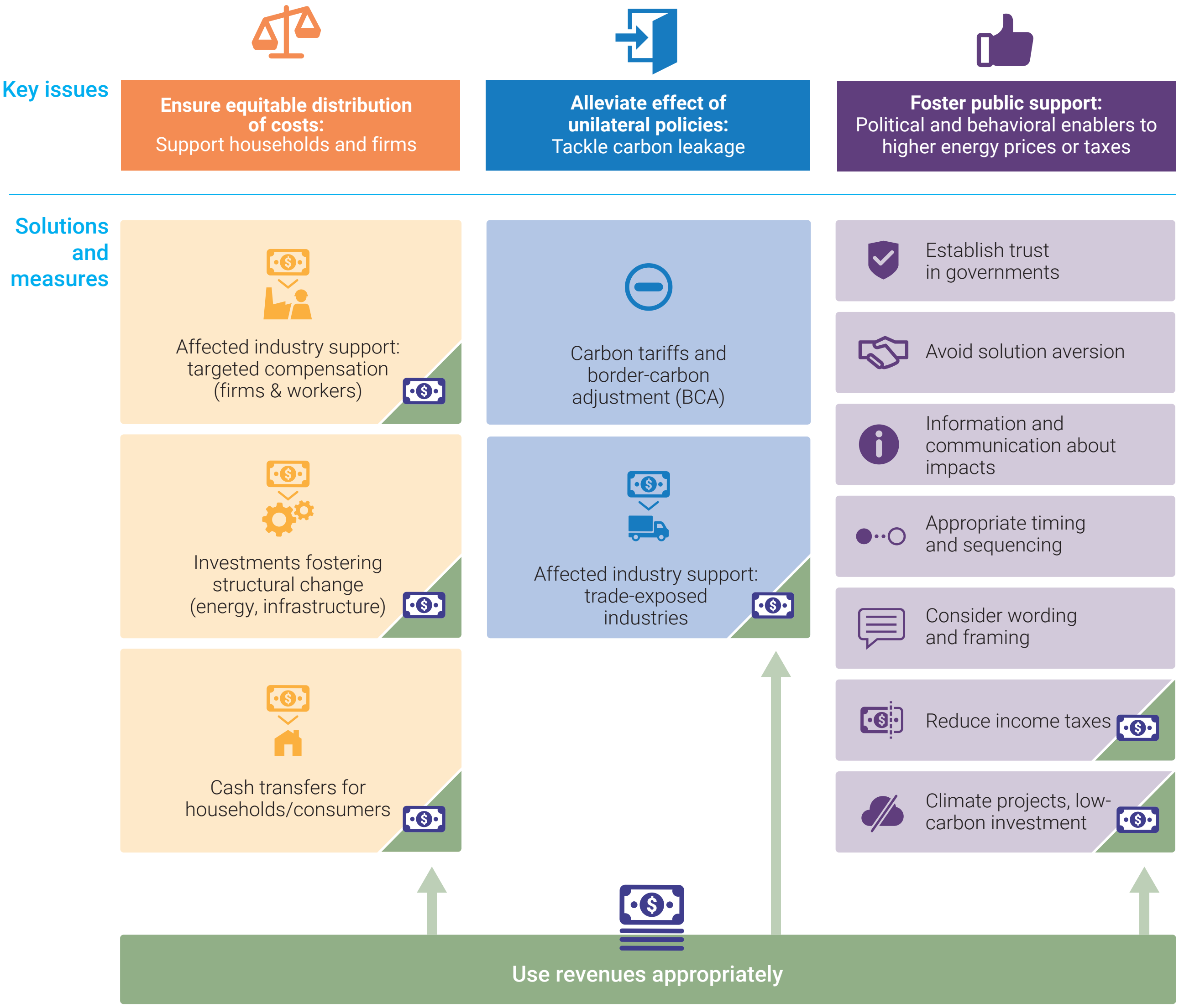
Non-state actors need to adopt common principles when formulating their actions. Such principles should include clear and quantifiable targets based on relevant benchmarks, technical capacity of the actors, availability of financial incentives and the presence of regulatory support.

6. **Fiscal policy reform can play a key role in creating strong incentives for low-carbon investments and reducing GHG emissions. Revenues from carbon pricing can be used for reducing other taxes, increase spending on social issues or compensating low-income households. Well-designed fiscal reform packages can reduce the costs of mitigating emissions, thereby making these fiscal reforms more socially acceptable. The use of carbon pricing to reduce GHG emissions is still only emerging in many countries and generally not applied at a sufficient level to facilitate a real shift towards low-carbon societies.**

Fiscal policy is a key government tool for managing and influencing the national economy and can be used to tax fossil fuels or subsidize low-emission alternatives as a way of influencing carbon emissions and ultimately investments in the energy sector.

Pricing of carbon emissions through taxes or domestic emissions trading systems is, in many countries, part of the national climate policy and is referenced in many NDCs as one of the possible policy tools to be used. Before 2005, when the Kyoto Protocol entered into force, hardly any emissions were covered by carbon taxes or

Figure ES.6: Key issues for making fiscal reforms politically viable (upper part) and solutions and measures to address them (lower part).



Note: The green arrows show different ways to use revenues from carbon pricing. Measures that are related to financial flows have a green mark.

trading systems. Coverage of explicit carbon pricing policies increased to about 5 percent of global GHG emissions between 2005 and 2010, primarily because of the introduction of the European Union's Emissions Trading System. Between 2010 and 2018, coverage rose to about 15 percent of global emissions, with 51 carbon pricing initiatives now in place or scheduled. If China implements carbon pricing as announced, coverage would rise to about 20 percent of global GHG emissions.

However, in most countries, fiscal policy is currently not yet geared towards delivering the required transition to a low-carbon economy. Effective carbon prices are too low and inconsistent, and the broader fiscal policy framework is often poorly aligned with climate policy goals. Besides carbon pricing, many governments levy specific taxes on energy use—partly to collect additional revenues. Even when considering energy-specific taxes together with explicit carbon pricing policies, half of the emissions from fossil fuels are not priced at all, and only 10 percent of global emissions from fossil fuels are estimated to be priced at a level consistent with limiting global warming to 2°C.

Studies show that a carbon tax of US\$70/tCO_2 in addition to existing measures could reduce emissions from just above 10 percent in some countries to more than 40 percent in other countries. Furthermore, in developing and emerging economies, an additional carbon tax of this order could raise the equivalent of 2 percent of gross domestic product (GDP) in public revenue.

Fiscal policies are used for different purposes and many countries actually subsidize fossil fuels for various economic and social reasons. If all fossil fuel subsidies were phased out, it would lead to a reduction of global carbon emissions of up to about 10 percent by 2030.

Innovation in solar photovoltaic (PV) technology illustrates both the nonlinear nature of innovation and how the various innovation policies reviewed drive and shape it. PV was deployed with a compound annual growth rate of about 38 percent from 1998 to 2015, continually defying forecasts. PV diffusion spurred cost reductions through 'learning by doing', scale economies and R&D, and also lower profit margins through increasing competition, which in turn stimulated further deployment of ever-cheaper systems. From 1975 to 2016, PV module prices fell by about 99.5 percent, and every doubling of installed capacity coincided with a 20 percent drop in costs. Public innovation policies were, and continue to be, crucial for this process across the innovation chain.

Several key issues need to be considered when introducing carbon pricing and phasing out fossil energy subsidies with the aim of reducing carbon emissions. These issues, along with possible ways of addressing them, are illustrated in figure ES.6 below. Embedding carbon pricing in fiscal reform packages that are progressive, equitable and socially acceptable, and incentivizing investment in new and job-creating industries is essential. It is instructive for policymakers to reflect on experience with other environmental fiscal reforms, where positively worded narratives, transparent communication, engagement with stakeholders and appropriate compensation have often helped overcome political and popular resistance to policies that increase fossil energy prices.

7. **Accelerating innovation is a key component of any attempt to bridge the emissions gap, but it will not happen by itself. Combining innovation in the use of existing technologies and in behaviour with the promotion of investment in new technologies and market creation has the potential to radically transform societies and reduce their GHG emissions.**

Based on an assessment of existing studies of what works, there are five key principles or 'success factors' that policymakers should consider when designing policies and programmes to accelerate low-carbon innovation:

1. Public organizations must be willing to take on the high, early-stage risk that private organizations shy away from.
2. At the mid-stage of the innovation chain, public organizations must be able to nurture feedback effects among different parts of the innovation landscape and help de-risk private investment in commercial-scale projects.
3. Green policies must set a direction for the whole economy, not for each sector separately.
4. Mission-oriented innovation is useful for stimulating investment and innovation across different parts of the economy to reach concrete, target-specific goals, such as X percent cost reduction in a specific low-carbon technology, by a specific date.
5. Policy instruments need to be structured to mobilize actors through bottom-up exploration and participation. All these policies benefit from a long-term design horizon that creates certainty for private finance to be crowded in.

While these principles apply to countries at any stage of economic development, a country's financial resources and technological capacity determine what types of concrete policies are most appropriate.

In order to illustrate these rather abstract concepts, the global solar photovoltaic (PV) technology development is presented as a case example of how application of the various innovation policy components has been driving and shaping PV technology and market development, with different countries in the lead during different periods.

The PV experience cannot be applied as a universal model, but it illustrates the various innovation success factors and the vision, patience and long-term thinking often required. Indeed, it is useful to reflect on how commercially viable, low-carbon technologies, such as PV and on-shore wind turbines, achieved their present status, when thinking about what is needed to reach new goals. For example, how can we deliver on the need for commercially viable and sustainable batteries and other power-storage technologies to rapidly reduce global transport-sector emissions by 2030? What kind of political vision and combination of public and private resources, at what scale, should be agreed upon and committed to in order to make this happen?

In addition to assessing the emissions gap, the Emissions Gap Reports cover opportunities for bridging the gap. Previous reports have demonstrated how proven policies and measures, if scaled up across countries and regions in terms of ambition, stringency and geographical reach can contribute to bridging the emissions gap, while supporting broader development goals. A summary of key areas and sectors covered in previous reports is provided at the back of this report.

Chapter 1. Introduction

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The year 2018 will most likely be the fourth warmest year on record since 1880, with the past five years the five warmest ever recorded (NOAA, 2018). In addition to increased temperatures, 2018 has experienced numerous other climate-related extremes, including devastating storms, floods, heatwaves and droughts, causing thousands of casualties and huge economic losses for citizens, companies and states. While it is difficult to attribute single events to climate change, the patterns are well aligned with the findings of the recently released Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C (IPCC, 2018). The report details how climate variability and extreme events will escalate with increased global temperatures and determines that many impacts will be irreversible, even if temperatures decrease again in the long term. This Emissions Gap Report has benefited significantly from the IPCC Special Report and its underlying studies and scenarios.

In its decision to adopt the Paris Agreement, the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), invited the IPCC to produce the special report on 'the impacts of global warming of 1.5°C above pre-industrial levels and related to global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty'.

The IPCC special report is a major scientific input to the political process of the United Nations Climate Convention, in which the Talanoa Dialogue plays a key role this year. Both the IPCC report and the Talanoa Dialogue are inputs to the stepwise 'ramping-up' mechanism of the Paris Agreement, created to address the huge gap between the level of ambition reflected by countries in their current Nationally Determined Contributions (NDCs) and the level required to achieve the goals of the Paris Agreement. The Paris Agreement specifies that countries must update their NDCs every five years and that each update should reflect progress in terms of enhanced ambition (UNFCCC, 2015). NDC updates will be informed by global stocktakes, the first of which will take place in 2023, leading to revised NDCs by 2025.

The 2018 Talanoa Dialogue[1] is an important precursor to the global stocktakes. It is convened by the UNFCCC as an inclusive, participatory and transparent dialogue about future ambitions and current actions, designed to take initial stock of countries' collective efforts and inform the preparation of new or updated NDCs to be communicated by 2020 (UNFCCC, 2015:4). The Dialogue consists of a preparatory and a political phase. During the preparatory phase, Parties and non-Party stakeholders are invited to submit inputs and participate in discussions addressing three questions: Where are we? Where do we want to go? How do we get there? So far, Parties and non-Party stakeholders have shared almost 500 stories, submitted over 280 written inputs and attended over 75 events (UNFCCC, 2018). This will be synthesized and presented at the 24th session of the Conference of the Parties (COP 24) in December 2018, where the political phase will take place, informed by the outcome of the preparatory phase, the IPCC special report and the forthcoming Yearbook of Global Climate Action (United Nations Climate Change Secretariat).

The Global Climate Action Summit held between 12 and 14 September 2018 in San Francisco was another significant event under the climate change political process. It brought together more than 4,500 local and regional government and business leaders and other non-state and subnational actors on climate change to showcase climate actions around the world (Global Climate Action Summit, 2018). The Summit resulted in more than 500 announcements to strengthen climate action by non-state and subnational actors.

1 Previously referred to as the 'Facilitative Dialogue', the Dialogue was re-named under the COP Presidency of Fiji in 2017.

This Emissions Gap Report is the 9th independent scientific assessment produced by UN Environment to assess how countries' mitigation actions and pledges are affecting the global greenhouse gas emissions trend, comparing it against the emission reductions necessary to limit global warming to well below 2°C and 1.5°C in accordance with the Paris Agreement. The difference between these is known as the 'emissions gap'. This report has been prepared at the request of numerous countries as an input to inform international climate negotiations as the full implementation of the Paris Agreement moves closer. A special pre-release version of chapter 5 of this report was published in time for the Global Climate Action Summit.

This year, the Emissions Gap Report has focused on providing information relevant to the Talanoa Dialogue, offering an updated assessment of the important roles and potential contributions of non-state and subnational actors to climate change, and updating and improving the gap assessment, using the most recent studies and scenarios.

The report is organized into seven chapters, including this introduction. Chapter 2 presents an update of current global emissions and assesses the trends and progress of G20 members towards achieving pledged 2020 emission reductions, the Cancun pledges and NDC emission targets. The chapter also considers whether global greenhouse gas emissions show signs of peaking, which is crucial for achieving the temperature targets of the Paris Agreement and depends on when emissions peak in individual countries, the level at which emissions peak and the rate of decline following this. Chapter 3 provides an updated assessment of global emission levels in 2030 consistent with the temperature goal of the Paris Agreement, based on the significantly expanded set of new least-cost scenarios, which were prepared in the context of the IPCC Special Report. Updated estimates of global emission levels in 2030 under different policy and NDC implementation scenarios are also provided. Together, these form the basis for an update of the 2030 emissions gap.

In line with previous editions, the report provides insight into how the emissions gap can be bridged. Chapter 4 presents an overview of options for enhancing the ambition of NDCs, while strengthening action through a suite of domestic policies targeting climate change. Chapter 5 assesses the role and potential of non-state and subnational actors in bridging the emissions gap, based on the most recent studies, while chapter 6 examines the role of fiscal policy reform in creating strong incentives for low carbon investments and reducing greenhouse gas emissions, with particular attention given to carbon pricing and taxation. Finally, chapter 7 assesses how accelerating innovation can help bridge the emissions gap, while also transforming societies. Previous Emissions Gap Reports have covered a number of other important areas and sectors with significant potential to bridge the emissions gap. A summary of these is provided at the back of this report.

This report has been prepared by an international team of 42 leading scientists from 25 scientific groups in 14 countries. As in previous years, a renowned steering committee guided the assessment, which followed a transparent and participatory production process. The assessment methodology and preliminary findings were made available to the governments of countries specifically mentioned in this report, which were invited to comment on the findings.

The information contained in the report provides important inputs to the current debate on global climate policy and the actions needed to meet the goal of the Paris Agreement. Meeting the 2030 targets is crucial for limiting the adverse impacts of climate change and creating the foundation necessary to develop more ambitious mitigation targets under the NDCs beyond 2030, aimed at achieving emission neutrality in the second half of this century alongside sustainable development and poverty eradication efforts.

UN Environment hopes that this 9th edition of the Emissions Gap Report will support the much-needed move towards enhanced ambition and accelerated action in the forthcoming climate negotiations in Katowice.

Chapter 2.
Trends and progress towards the Cancun pledges, NDC targets and peaking of emissions

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2.1 Introduction

This chapter examines the latest trends in greenhouse gas (GHG) emissions and progress towards achieving both the Cancun pledges and Nationally Determined Contributions (NDCs). Particular focus is given to the peaking of emissions at the global and national levels (section 2.2), the current status and recent trends of global GHG emissions and for emitting countries (section 2.3), and whether GHG emissions are peaking at the national level and the implications for global peaking. In addition, this chapter also assesses whether countries are on track to meet their Cancun pledges and NDC targets and provides and update of recent policy developments in G20 member countries (section 2.4).

2.2 Peaking of greenhouse gas emissions

To limit global warming to well below 2°C and 1.5°C, global GHG emissions have to peak and decline rapidly thereafter. Mitigation pathways consistent with a likely chance of achieving the temperature targets require that, global emissions peak by 2020. The Paris Agreement suggests that Parties should collectively aim to reach global peaking of GHG emissions “as soon as possible”, recognizing that “peaking will take longer for developing country Parties” and should be guided by the principle of equity, acknowledging common but differentiated responsibilities and capabilities.

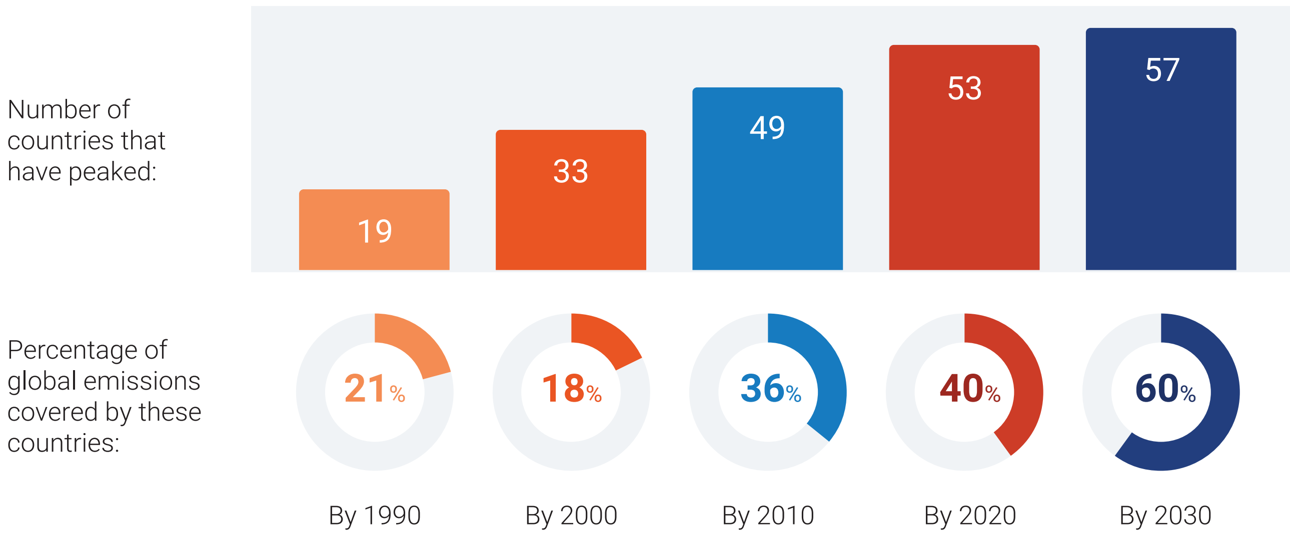
Global and national peaking of emissions and the ability to meet the climate objective of the Paris Agreement are dependent on three factors: the timing of national and global peaking, the level of emissions peaking and the rate of decline in emissions following the peak. It is therefore crucial that countries not only commit to peaking their emissions at lower levels, but that they achieve this as soon as possible and that the subsequent rate of emissions decline is substantial (Levin and Rich, 2017). Although this applies to all countries, major emitters play a key role in determining when and at what level global emissions peak. This chapter therefore pays particular attention to G20 members, who currently account for around 78 percent of global GHG emissions.

Figure 2.1 shows the steady progress from 1990 to 2030 in the number of countries that have either peaked their emissions or are expected to do so, provided that they meet their commitments, alongside the percentage of global emissions of these countries. By 2030, up to 57 countries representing 60 percent of global emissions will have peaked, if they fulfil their commitments.

A country is considered to have peaked its emissions if two criteria are met: its emissions reached their maximum level at least 5 years before the most recent GHG inventory year; and the country has unconditionally committed to continue lowering its emissions below the peak emissions level in the future. In some countries classified as having peaked, emissions declined after the initial peak year and then increased again, rather than declining steadily after the initial peak year. Despite these fluctuations, the initial peak year is still considered as the peak, since emissions are below this maximum emission level.[1]

1 See Levin and Rich (2017) for a full discussion of the methodology and assumptions on how peaking was determined. One limitation of the referenced study is that it takes countries’ commitments at face value by assuming they will be achieved by the target date, without considering whether targets will be underachieved or overachieved.

Figure 2.1: Number of countries that have peaked or are committed to peaking their emissions, by decade (aggregate) and percentage of global emissions covered (aggregate).



Source: Levin and Rich (2017).

Of the 19 countries that peaked their emissions in or prior to 1990, 16 were former Soviet republics or economies in transition or both.[2] Other countries that peaked by 1990 include Germany and Norway. By 2010, 39 of the world's 43 Annex I countries peaked their emissions. The 10 non-Annex I countries that peaked by 2010 or earlier are Azerbaijan, Brazil, Costa Rica, Georgia, Micronesia, Moldova, Montenegro, San Marino, Serbia and Tajikistan. Brazil is the first major emitting developing country to peak their emissions, reaching a maximum level in 2004.[3]

By 2020, all but one Annex I country (Turkey, an emerging economy) are expected to have peaked their emissions. 15 non-Annex I countries are committed to peaking their emissions by 2030 or sooner, including China (for CO_2 only) and Mexico,[4] among others.

By 1990, three G20 members (the EU28, Germany and Russia)[5] had peaked emissions. Half of G20 members (additionally, Australia, Brazil, Canada, France, Italy, the United Kingdom, and the USA) had peaked emissions by 2010 and another four member countries' emissions will peak by 2020 (Japan and the Republic of Korea), or by 2030 (China (for CO_2 only) and Mexico) if commitments are achieved. Given existing unconditional commitments, six G20 members' GHG emissions show no sign of peaking, (Argentina, India, Indonesia, Saudi Arabia, South Africa[6] and Turkey).

Figure 2.1 indicates that the number of countries expected to peak by 2030 and the share of global emissions they represent is insufficient for global emissions to peak in the near future. The following sections provide further insight into issues relating to the timing of national and global peaking, the level of emissions peaking and the rate of decline in emissions following peaks, examining the status and trends in current global emissions and progress of G20 members.

2.3 Current global emissions: status and trends

Total GHG emissions[7,8,9] have increased steadily since 1970, with trend variations usually explained by changes

2 It should be noted that while some of these countries' commitments for 2020 and 2030 indicate an intended increase from recent emissions levels (e.g. Russia), future commitments do not propose to surpass 1990 emissions levels.

3 Brazil's peak and subsequent decline in emissions reduction is primarily the result of actions to reduce deforestation in the Amazon region (Azevedo, T. R. *et al.* (2018)). Any reversal of policy implementation could lead to increased emissions. Brazil's emissions, excluding land use, land-use change and forestry (LULUCF), have not yet peaked.

4 Mexico's NDC mentions "a net emissions peak starting from 2026" (UNFCCC, 2016).

5 Russia's emissions peaked prior to 1990. Although Russia's commitments for 2020 and 2030 indicate an intended increase from recent emissions levels, its future commitments do not propose to surpass 1990 emissions levels.

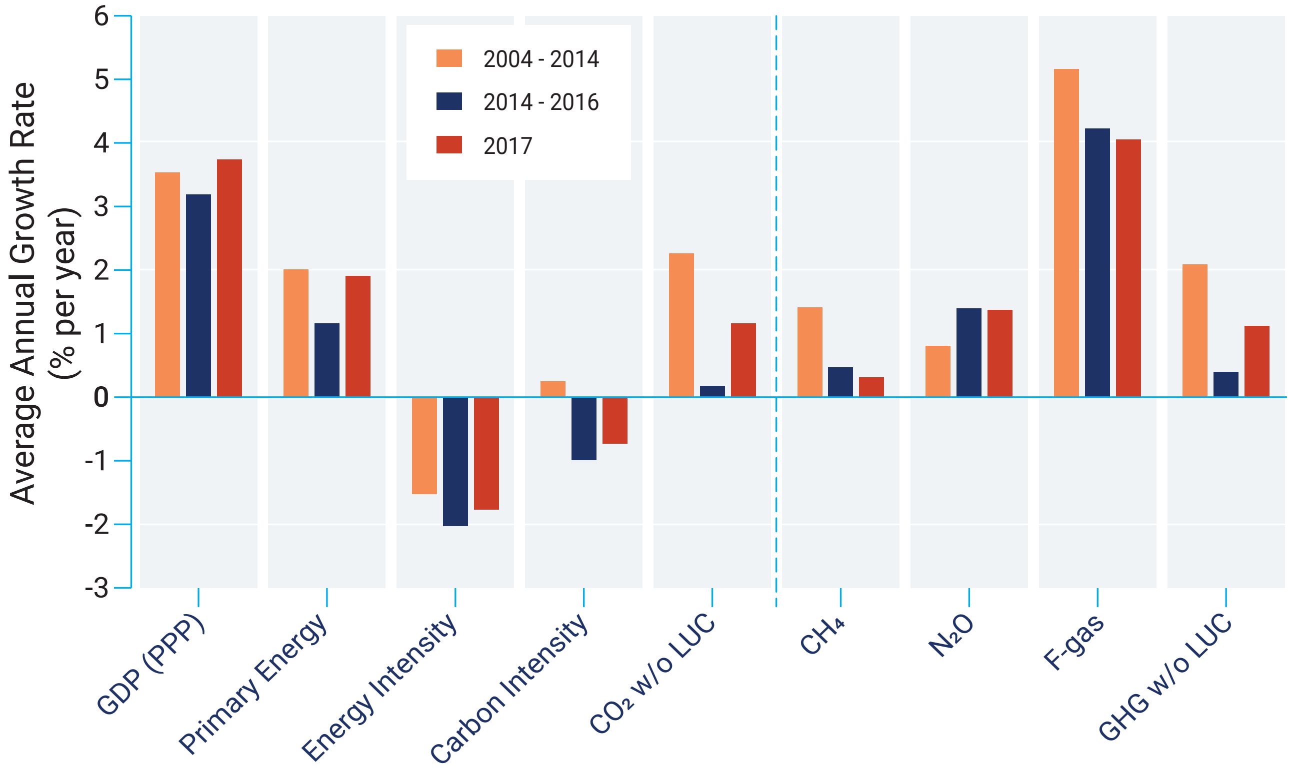
6 As a conservative assumption, South Africa is not considered as having a firm commitment to peak, since there is no guarantee that the conditions upon which they made the pledge will be met.

7 This analysis is based primarily on GHG emissions data (fossil and industry CO_2 and sources of CH_4, N_2O and fluorinated gases, but excluding land use CO_2) using EDGAR v5.0 (CO_2)/v4.3.2 FT2017 for non-CO_2 gases (Olivier *et al.*, 2018). The largest changes compared with v4.3.2 FT2016 (Olivier *et al.*, 2017) are in the CO_2 emissions, since the energy consumption data have been revised and expanded to include updated energy statistics from the International Energy Agency (IEA) for the whole time series to 2015 instead of to 2012 (from v4.3.2 to v5.0) and revised BP statistics for the latest years. Furthermore, revisions for cement clinker and gas flaring were made using updated statistics, which also changed the data before 2012, and the coverage of 3 other sources was improved (ethylene production, other chemical product use and waste incineration).For non-CO_2 sources updated statistics from IEA, BP, the Food and Agricultural Organization of the United Nations (FAO) and UNFCCC (reported data), among others were used to estimate the 2012–2017 CH_4 and N_2O emissions. This means that statistics-based emissions are now updated to 2016 or 2017, with new statistics and several revisions available for previous years. In total, these revisions show that total GHG emissions are roughly 0.9 $GtCO_2e$ higher than figures presented in recent Emissions Gap Reports.

8 There are various estimates of emissions from LUC based on different system boundaries (Grassi *et al.*, 2018) and different methods (Le Quéré *et al.*, 2018). There is no commonly accepted value of emissions from LUC, with different estimates giving different emission levels and trends (Le Quéré *et al.*, 2018). Global emissions from LUC also have large inter-annual variability driven by weather phenomena (e.g. El Niño). For this reason, LULUCF is not a focus of the analysis of global or country GHG trends.

9 Alternative datasets exist (particularly for CO_2 emissions), though they generally lead to the same conclusions due to similar growth rates. For this reason, the discussion focuses only on one dataset.

Figure 2.2: Average annual growth rates of key drivers of global CO_2 emissions (left of dotted line) and components of greenhouse gas emissions (right of dotted line).



Note: Emissions from LUC are not included due to large inter-annual variability.

in economic output (such as recessions, Peters *et al.*, 2011). In 2017, the total GHG emissions, excluding emissions from land-use change (LUC),[10] reached a record 49.2 $GtCO_2e$.[11] Including LUC adds another 4.2 $GtCO_2$, bringing the total to 53.5 $GtCO_2e$, which is an increase of 0.7 $GtCO_2e$ (1.3 percent) compared with 2016. All GHGs have shown strong growth in the last decades (figure 2.2), except for emissions from LUC, which have remained relatively steady.

From 2014 to 2016 there was a distinct change in the GHG emissions trend (excluding the more variable emissions from LUC), even though the economy continued growing (figure 2.2).

The slowdown brought renewed optimism to climate policy discussions, since it may indicate a necessary peak in global GHG emissions. Preliminary estimates of global GHG emissions suggest they grew[12] 1.1 percent in 2017, leaving considerable uncertainty as to whether short-term economic factors were primarily responsible for the 2014–2016 slowdown.

Since CO_2 emissions from fossil fuels and industrial processes dominate total GHG emissions, changes in CO_2 emissions have the largest influence on GHG emission trends. Despite the strong growth in economic activity (Gross Domestic Product (GDP)) from 2014 to 2016, growth in energy consumption and CO_2 emissions from fossil fuels, industry, and cement slowed due to faster than expected declines in energy and carbon intensity (figure 2.2). Other GHGs (methane (CH_4), nitrous oxide (N_2O), fluorinated gases) continued to grow from 2014 to 2016, but with smaller changes compared with the decadal trend (figure 2.2).

Global CO_2 emissions from fossil fuels and industrial processes grew at an annual rate of 2.3 percent from 2004 to 2014. During 2014–2016 emissions had no growth despite the economy growing 3.2 percent/year, meaning that energy and carbon intensity reduced faster in these years than in the previous decade. The increase in global CO_2 emissions in 2017 (1.2 percent) resulted from stronger Gross Domestic Product (GDP) growth (estimated at 3.7 percent) and slower declines in energy

10 The scientific community uses different definitions for land-use change emissions compared to UNFCCC, leading to higher estimates in section 2.2 compare to the rest of the report (Grassi *et al.*, 2018).

11 Calculated using the Global Warming Potentials metric from the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), similar to the 2017 Emissions Gap Report.

12 Growth rates are not adjusted for leap years.

and especially carbon intensity. The 2017 growth raises concerns that the progress made in the 2014–2016 period may be short-lived.

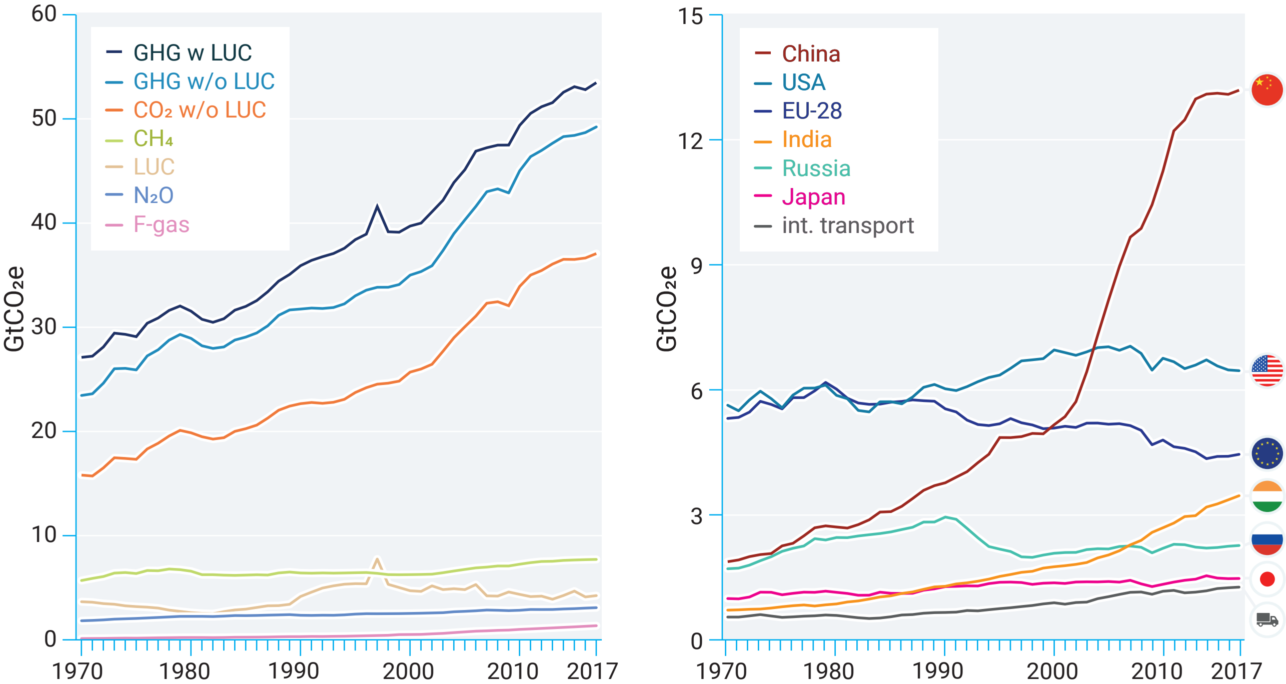
Global CO_2 emissions from LUC are less strongly linked to economic activity, more volatile owing to changes in climatic conditions and uncertain due to purely constrained input data (Le Quéré *et al.*, 2018). For these reasons, CO_2 emissions from LUC are often considered independently from emissions from fossil fuels and industrial processes. Over the last decade, emissions from LUC accounted for 10 percent of total GHG emissions, a share that is declining due to the strong growth in emissions from fossil fuels and industrial processes. Emissions from LUC have remained relatively stable for decades, albeit with high uncertainty on the level and trend of these (Le Quéré *et al.*, 2018). In 2015, emissions from LUC were relatively high due to El Niño causing hotter and drier conditions in the tropics, resulting in more intense fires and thus more rapid growth in CO_2 concentration in the atmosphere (Peters *et al.*, 2017; WMO, 2017).

The remaining GHGs (CH_4, N_2O, fluorinated gases) are responsible for 25 percent of GHG emissions over the last decade when excluding LUC, rising to 32 percent when including LUC.[13] Non-CO_2 GHGs have grown at roughly half the rate of CO_2 emissions since 1990. CH_4 emissions are responsible for 16 percent of global GHG emissions (excluding LUC) over the last decade and grew at an annual rate of 1.4 percent from 2004 to 2014 and only 0.5 percent from 2014 and 2016, with growth estimated to be 0.3 percent in 2017. Concentrations of CH_4 in the atmosphere have grown faster than expected in the last decade (Saunois *et al.*, 2016), primarily due to biogenic emissions in the tropics and fossil fuel emissions in temperate regions (Worden *et al.*, 2017), though scientific debate on the causes continues.

N_2O emissions are responsible for 6.3 percent of GHG emissions (excluding LUC) and had more rapid growth from 2014 to 2016 (1.4 percent/year) and 2017 (1.4 percent) than from 2004 to 2014 (0.8 percent/year), compared with other gases. Fluorinated gases (hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6)) are only responsible for 2.4 percent of total GHG emissions and continue to have strong growth at around 5 percent/year.

While global emissions statistics provide important information on collective progress, they mask the dynamics at the country level (figure 2.3). The 2014–2016 slowdown in the growth of global emissions and the return to modest growth in 2017 is indicative of countries' underlying behaviour. The top 4 emitters (China, USA, EU28 and India) contribute to over 56

Figure 2.3: Global greenhouse gas emissions per type of gas (left) and top greenhouse gas emitters excluding land-use change emissions due to lack of reliable data (right).



Source: EDGAR v5.0/v4.3.2 FT2017 CO_2 (Olivier *et al.*, 2018) and Global Carbon Project (Le Quéré *et al.*, 2018).

13 Weighted using a Global Warming Potential of the IPCC Second Assessment Report and 100 years as the time period, which is common in climate policy.

percent of the total GHG emissions over the last decade when excluding LUC, the top 7 (including Russia, Japan and international transport) account for more than 66 percent, while G20 members contribute 78 percent. Aggregated GHG emissions from G20 countries grew at 2.1 percent/year from 2004 to 2014, remained relatively steady from 2014 to 2016 and are estimated to grow 0.9 percent in 2017. Even though emission reductions are needed from all countries, the top emitters are responsible for most of the changes in global emissions.

China emits more than one quarter (27 percent) of global GHG emissions (excluding LUC), and the ups and downs of Chinese emissions leave an important signature on global emissions growth. From 2004 to 2014, Chinese GHG emissions grew at an annual rate of 6 percent (accounting for two thirds of global emissions growth), before declining slightly from 2014 to 2016. The slowdown during the 2014–2016 period was across all GHGs, though CO_2 dominated the trend due to a marked decline in coal consumption. Some reports have speculated that Chinese emissions, more specifically coal consumption, may have peaked (Qi *et al.,* 2016). However, the increase of 1.2 percent in global CO_2 emissions in 2017, due to renewed growth of emissions at a rate of 0.9 percent, suggests that it may be too soon to consider Chinese emissions to have peaked.

The European Union (EU) and USA play key strategic roles in global climate policy due to their historical responsibility, and together account for more than 20 percent of global GHG emissions (13 percent for the USA and 9 percent for the EU, excluding LUC). Emissions in the USA likely peaked in 2007 and decreased at an annual rate of 0.4 percent from 2004 to 2014. The rate of reductions increased from 2014 to 2016 (annual declines of 2 percent), with significant drops in 2015 and 2016 due to less coal-powered electricity generation. Emissions decreased slightly in 2017 by 0.3 percent. Reductions have been strongest for CO_2 emissions, but there has been strong growth in fluorinated gas emissions. This indicates that the USA made considerable contributions to the observed slowdown in global GHG emissions growth for the 2014–2016 period.

The EU has had steady declines in GHG emissions since 1990, with accelerated reductions of 2 percent/year from 2004 to 2014. However, EU emissions have been increasing since 2014 (on average 1 percent/year), reversing the long-term trend. Increases in CO_2 emissions due to strong growth in oil and gas use are largely responsible for the overall rise, though N_2O emissions have also increased and the growth of fluorinated gas emissions has also remained strong. CH_4 emissions continued to decline but at a slower rate.

Due to its large population, India's GHG emissions represent 7.1 percent of the global total, despite its low per capita emissions and large parts of the population needing better living standards. Indian emissions grew strongly in the 2004–2014 period, at an annual rate of 5 percent, with only a slight respite during the 2014–2016 period, when the annual rate dropped to 3 percent. India's GHG emissions are estimated to grow at a rate of 3 percent in 2017 due to the demonetization process (removal of some rupees from circulation) and the introduction of a goods and services tax.[14]

Although the top 4 countries represent 56 percent of global GHG emissions (excluding LUC), this does not downplay the importance of the remaining countries. GHG emissions in the Russian Federation are 4.6 percent of the global total and since 2014 have continued to grow by about 1 percent/year (excluding LUC). In Japan, GHG emissions (2.9 percent of the global total) have declined on average 1 percent/year since 2014, despite significant fluctuations following the Fukushima Daiichi nuclear disaster. Emissions from international aviation and marine transport, which represent 2.5 percent of global GHG emissions, have grown strongly at an annual rate of over 2 percent since 2014.

Despite a distinct slowdown in emissions growth from 2014 to 2016, initial data for 2017 indicates GHG emissions have started to increase, both globally and in key countries. It is unclear whether the 2017 growth trend will be sustained in the next few years or whether 2017 will just be an anomalous year as global emissions reach a plateau. While it seemed that global GHG emissions could peak in the near future, recent changes have now delayed this.

2.4 Assessment of current policies: are G20 members on track to meet the Cancun pledges for 2020 and NDC targets for 2030, and to peak their emissions?

2.4.1 Overview and comparison of G20 members

As G20 members currently account for around 78 percent of global emissions, they will greatly influence the achievement of the Paris Agreement climate goal. This section provides an update of the extent to which G20 members are putting in place and implementing policies that enable them to meet the Cancun pledges and NDCs. In addition, it offers an overview of G20 members' respective shares of global emissions, the implications of their unconditional NDCs for per capita emissions and where they stand with respect to peaking of emissions and decarbonization rates. Table 2.1 provides a comparative overview of this information for all G20 members (with the EU28 represented collectively instead of as the four Member States that are also individual G20 members).

Collective progress towards the Cancun pledges and NDCs

G20 members are collectively projected to achieve the conditional end of the Cancun pledges for 2020 under current policies. However, as table 2.1 indicates, six G20

14 https://www.carbonbrief.org/guest-post-why-indias-co2-emissions-grew-strongly-in-2017.

members (Canada, Indonesia, Mexico, the Republic of Korea, South Africa, the USA) are either not projected to achieve their Cancun pledges, or have uncertainty on whether they will achieve it.

At present, G20 countries are collectively not on track to meet their unconditional NDCs for 2030. Based on an assessment of current policies, around half of G20 members fall short of achieving their unconditional NDCs (Argentina, Australia, Canada, EU28, the Republic of Korea, Saudi Arabia, South Africa and the USA) (table 2.1 and figure 2.4). Under current policies, three G20 members (Brazil, China and Japan) are on track to meet their NDC targets, while emissions under current policies of three additional countries (India, Russia and Turkey) are projected to be more than 10 percent below their unconditional NDC targets. It is uncertain whether two countries (Indonesia and Mexico) are on track to meet their NDC targets in 2030 under current policies.

It is estimated that G20 members will need to implement additional policies to reduce GHG emissions further by about 2.5 $GtCO_2e$/year to achieve their unconditional NDCs and 3.5 $GtCO_2e$/year to achieve their conditional NDCs by 2030. The estimate of additional reductions needed has decreased by approximately 1 $GtCO_2e$ compared with 2017, due to lower projections of emission reductions under current policies in China, the EU28 and the USA.

It is important to note that a country likely to meet or exceed its NDCs based on current policies is not necessarily undertaking more stringent mitigation action than a country that is not on track. It can also indicate that the ambition of the current NDC could be enhanced. According to the Paris Agreement, countries are obliged to regularly update and strengthen their NDCs. The assessment conducted in this section is based on current NDCs, recognizing that they are to be revised and should be strengthened considerably by 2020 to reduce global emissions to levels consistent with limiting global warming to below 2°C or 1.5°C by 2030 (see chapter 3).

Peaking of emissions and decarbonization rates

Countries that have historically peaked have a critical role to play in determining the timing and level of global emissions peaking, as each country's decarbonization rate after peaking will be a defining factor for global cumulative emissions. Countries that have already peaked their GHG emissions have not reduced their emissions at fast enough rates since the peak year. For example, an 80 percent reduction of emissions between 2005 and 2050 requires a constant annual reduction rate of 3.5 percent/year for the period. By contrast, the G20 members that have peaked show constant annual emission reduction rates ranging between 0.6 percent/year (Canada) and 2.5 percent/year (Russia) up to 2016 for all GHG emissions, including land use, land-use change and forestry (LULUCF) (table 2.1). Brazil, the only non-Annex I member of the G20 that has peaked its GHG emissions to date, showed an average reduction rate of 12 percent/year between 2004 and 2012 due to the large reductions in emissions from LULUCF. Brazil's GHG emissions from non-LULUCF sectors have increased by 2.4 percent/year on average (table 2.1).

Table 2.1: Overview of the status and progress of G20 members, including on Cancun pledges and NDC targets.

Country	Share of global GHG emissions in 2017[a]	On track to meet the targets with current policies?		Unconditional NDC: per capita[b] GHG emissions		Emission peaking	
		Cancun pledges	Unconditional NDC	tCO_2e/cap in 2030[c]	versus 2015 levels	Peaking year[d]	Average annual growth after peaking[e]
Argentina	0.8%	No pledge	No	9.8	-6%	No commitment to peak	---
Australia	1.2%	Yes	No	15.4	-29%	2006	-1.6%/year
Brazil	2.3%	Yes	Yes	5.3	-22%	2004	(2006–2016) -12.0%/year (2004–2012) (+2.4%/year excluding LULUCF)
Canada	1.6%	No	No	12.9	-33%	2007	-0.6%/year (2007–2016)
China	26.8%	Yes	Yes	10.0	+17%	By 2030 (CO_2 only)	---
EU28	9.0%	Yes	No	6.1	-23%	1990 or earlier	-1.1%/year (1990–2016)
India	7.0%	Yes	Yes*	3.5	+67%	No commitment to peak	---
Indonesia	1.7%	Uncertain	Uncertain	6.9	+15%	No commitment to peak	---
Japan	3.0%	Yes	Yes	8.6	-13%	By 2020	---
Mexico	1.5%	Uncertain	Uncertain	5.1	-2%	By 2030	---
Republic of Korea	1.6%	No	No	10.1	-21%	By 2020	---
Russian Federation	4.6%	Yes	Yes*	18.9	+33%	1990 or earlier (former Soviet republic)	-2.5%/year (1990–2016) +0.5%/year (2000–2016)
Saudi Arabia	1.5%	No pledge	No	23.1	+19%	No commitment to peak	---
South Africa	1.1%	Uncertain	No	9.5	0%	No commitment to peak	---
Turkey	1.2%	No pledge	Yes*	10.5	+102%	No commitment to peak	---
United States of America	13.1%	Uncertain	No	14.0 (2025)	-25% (2025)	2007	-1.5%/year (2007–2016)

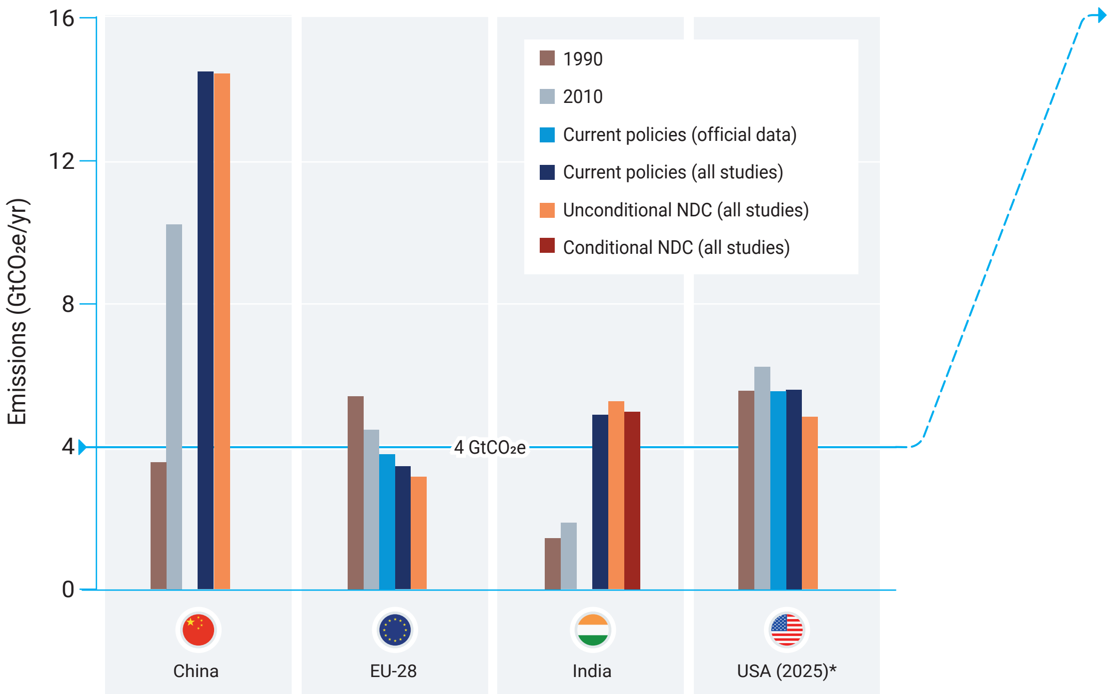
Notes:
a Olivier *et al.* (2018), excluding LULUCF.
b Population projections are based on the medium fertility variant of the United Nations World Population Prospects 2017 edition (UN DESA, 2017).
c The G20 average in 2015 was 7.5 tCO_2e/cap (based on national GHG inventories and using the EDGAR GHG trend if emissions for the latest years were missing). Using EDGAR estimates only, the G20 average in 2015 was 8.0 tCO_2e/cap (Olivier *et al.*, 2017).
d Given the unconditional pledges. Expected peak years are based only on commitments that countries have made and assume the achievement of such commitments.
e Authors' calculations based on UNFCCC (2018) data (including LULUCF). For Australia and Canada, the peak years based on 2018 GHG inventories were 2007 and 2004 respectively, which differs from those assessed by Levin and Rich (2017), since they used older inventory data. Peak years reported by Levin and Rich (2017) are used here for the calculations. The average emission growth rates were -1.8 percent/year for Australia with 2007 as the peak year and -0.5 percent/year for Canada with 2004 as the peak year.
* Denotes that the current policy trajectory is more than 10 percent below the NDC target.

To assess whether the changes in emission-related indicators as a result of NDCs are both ambitious and fair (in line with the long-term goal of the Paris Agreement) would require a thorough evaluation of normative indicators of burden-sharing indicators, which is beyond the scope of this report. However, a number of recent peer-reviewed studies attempt this task, based on various effort-sharing considerations (Höhne *et al.*, 2014; Pan *et al.*, 2017; Robiou du Pont *et al.*, 2017; CAT, 2018a; Holz *et al.*, 2018).

Figure 2.4 provides a detailed comparison of estimated emissions under current policies and the full implementation of NDCs for all G20 members, mapping these against 1990 and 2010 emissions. For each of the G20 members, median GHG emission projections have been calculated for current policies and full implementation of the NDC, using information from a recently published study (den Elzen *et al.*, forthcoming), which updates and expands the data sources covered in the 2017 Emissions Gap Report (UNEP, 2017), using the most up-to-date data from countries' recently published National Communications, 3rd biennial reports of 7 G20 members, and several other new national studies for policies and NDC projections. The estimates draw on official country data and independent sources (see den Elzen *et al.* 2018 for further details). GHG emission projections under current policies from independent analyses presented in this chapter cover main energy and climate policies implemented by a recent cut-off date and do not consider prospective policies that are being debated or planned. Similarly, current policy and NDC estimates only partially cover commitments and actions made by non-state and subnational actors to date and do not fully reflect the implications of recent significant declines in the cost of renewable energy sources. The role and potential of non-state and subnational actors is assessed in chapter 5, while chapter 7 discusses the role of innovation policy and market creation.

Figure 2.4: Greenhouse gas emissions (all gases and sectors) of the G20 and its individual members by 2030 under different scenarios and compared with historical emissions.

Figure 2.4a.



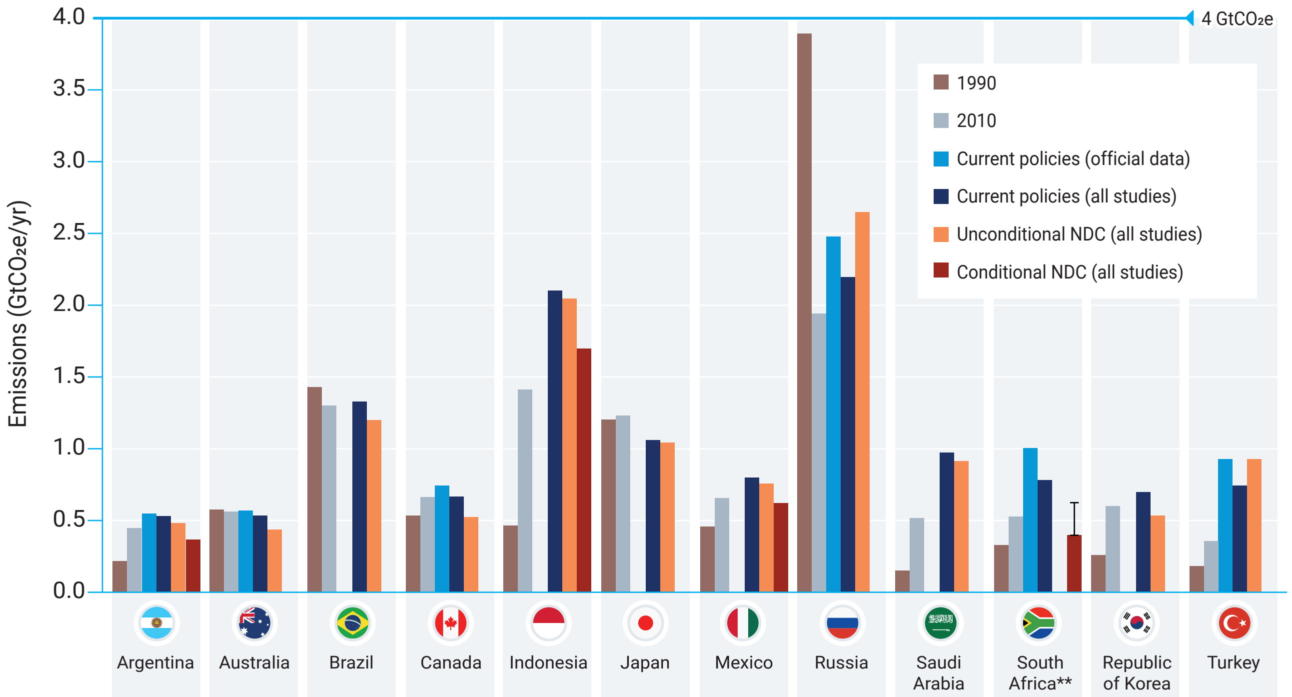
Notes:
For reporting reasons, the emission projections for China, the EU, India and the USA are shown in figure 2.4a with and the other countries shown in figure 2.4b, using 2 different vertical axes.
As a conservative assumption, South Africa is not considered as having a firm commitment to peak, since there is no guarantee that the conditions upon which they made the pledge will be met.
* For the USA, the unconditional NDC is for 2025.

2.4.2 Emissions trends and targets of individual G20 members[15]

Argentina's revised NDC introduced at COP 22 in 2016 presents an unconditional GHG emissions target of 483 $MtCO_2e$/year by 2030 and a further conditional target of 369 $MtCO_2e$/year (Government of Argentina, 2016). If the unconditional target is met, emissions would increase by 19 percent above 2010 levels in 2030. The current policies scenario projected by Climate Action Tracker for 2030 (CAT, 2018b) was lowered by about 5 percent from its projection in 2016. Nevertheless, Argentina is likely to miss its NDC targets if it does not change its current policies (Ministry of the Environment and Sustainable Development Argentina, 2015).

To help achieve its NDC targets, the Government of Argentina established a National Cabinet for Climate Change to facilitate discussions and agreements between 17 ministries on policies and measures to be implemented relating to the targets. These discussions have resulted in the development of mitigation action plans for the energy, forestry and transport sectors, with plans for industry, infrastructure and agriculture to be introduced shortly. The action on implementing renewable energy in Argentina's energy mix is particularly notable and is supported by 2 laws, one promoting renewable energy and implemented primarily through the RenovAr programme (which auctions renewable power capacity) and the other introducing distributed generation (though implementation is pending detailed ruling). The entire package of unconditional actions in sectoral plans is expected to reduce emissions by approximately 110 $MtCO_2e$/year by 2030 compared with the baseline. The success of these mitigation actions in achieving the 2030 unconditional NDC target depends on several factors, including the opposition of civil society to the construction of two mega hydroelectric dams in Patagonia and to two new nuclear power plants, and the country's recurrent financial constraints to sustain the implementation of some actions, such as the RenovAr program.

Figure 2.4b.



** South Africa's Intended Nationally Determined Contribution (INDC) is based on an emissions trajectory with an emissions range of 398–614 $MtCO_2e$ including LULUCF over the 2025–2030 period.

15 For a more comprehensive assessment of climate change mitigation policies including sector- and technology-specific policies in G20 countries, see, for example, Climate Transparency (2017).

Under its Cancun pledge, **Australia** proposed 3 targets for 2020 with different conditions: 5 percent, 15 percent and 25 percent below emission levels in 2000. The goal of 5 percent currently stands as Australia's unconditional pledge. In accordance with the Kyoto Protocol, Australia uses a carbon budget approach that accounts for cumulative emissions between 2013 and 2020 in order to assess progress against its pledge. For the budget period, Australia is on track to overachieve its 2020 target by 166 $MtCO_2e$ without including carry-over from the Kyoto Protocol's 1st commitment period and by 294 $MtCO_2e$ with carry-over (Department of the Environment and Energy, 2017b). Independent studies consider the year 2020 in isolation and find Australia's current policy trajectory close to achieving its target.

In its NDC, Australia announced a 26–28 percent reduction below 2005 levels of GHG emissions by 2030 (UNFCCC, 2016). There has been no improvement in Australia's climate policy since 2017 and emission levels for 2030 are projected to be well above the NDC target. The latest projection published by the government shows that emissions would remain at high levels rather than reducing in line with the 2030 target (Department of the Environment and Energy, 2017a; CAT, 2018c). The Emissions Reduction Fund, which aims to purchase emissions reductions at the lowest available cost through auctions, and its safeguard mechanism are the main existing policies.

Brazil's Cancun pledge aims to reduce GHG emissions in 2020 by 36.1–38.9 percent compared with business as usual and its NDC target aims to reduce emissions to 1.3 $GtCO_2e$/year by 2025 with the emission level dropping to 1.2 $GtCO_2e$/year by 2030 (37 percent and 43 percent below 2005 levels respectively). Recent independent studies suggest that current policy scenario projections are well below the Cancun pledge level and in line with the NDC targets (Kitous *et al.,* 2017; Kuramochi *et al.,* 2017a; CAT, 2018d). GHG emission projections have been revised downward compared with previous year's (referenced in the 2017 Emissions Gap Report). Uncertainty remains about the future of the country's GHG emissions growth. For example, emissions from LULUCF reduced by 86 percent between 2005 and 2012 (Ministry of Science, Technology and Innovation, 2016), but recent data and analyses suggest that the decreasing trend for deforestation and the resulting reductions in GHG emissions have slowed down or even stopped (Azevedo *et al.,* 2018). In fact, the recent political crisis in the country has forced a weak government to concede reversals in environmental regulation as a bargaining chip to maintain power, which may potentially impact GHG emissions from land use as well as Brazil's contribution towards global climate targets (Rochedo *et al.,* 2018). The newly elected president of Brazil has indicated that he wants to limit environmental constraints on agriculture.

In February 2018, the National Congress approved the National Biofuels Policy (RenovaBio – Decree No. 9.308), which seeks to boost the use of renewable fuels and expand its share in the energy mix. Recent electricity auctions have targeted solar energy, signalling a potential increase in solar capacity in the country in the coming years. Existing contracts for solar electricity in operation and under construction total around 4 GW nominal capacity (CCEE, 2018).

Canada pledged to reduce its economy-wide GHG emissions by 17 percent below 2005 levels by 2020 and 30 percent by 2030 (UNFCCC, 2014; UNFCCC, 2016). Canada could achieve its 2020 target under a low economic growth scenario, but it is not likely to achieve its NDC target (Government of Canada, 2017; CAT, 2018e). However, recent analysis suggests that Canada's emissions will be 4–6 percent lower in 2030 than projected in 2016, suggesting that progress is being made towards the target (Kitous *et al.,* 2017; Kuramochi *et al.,* 2017a; PBL, 2017; CAT, 2018e). In October 2017, Canada published regulations to phase down the production and consumption of HFCs in accordance with the Kigali Amendment. Canada is also planning a federal carbon pricing backstop system to enforce carbon pricing in provinces that have not implemented a provincial system by the end of 2018 (Government of Canada, 2017).

China pledged to reduce the intensity of CO_2 emissions by 40–45 percent by 2020 and its NDC includes 4 major targets for 2030: (1) peak CO_2 emissions around 2030, making best efforts to peak earlier; (2) reduce the carbon intensity of Gross Domestic Product (GDP) by 60–65 percent from 2005 levels; (3) increase the share of non-fossil fuels in primary energy consumption to around 20 percent; and (4) increase the forest stock volume by around 4.5 billion m^3 from 2005 levels. Independent studies, including those recently published (Sha *et al.,* 2015; den Elzen *et al.,* 2016; IEA, 2017; CAT, 2018f), suggest that China will likely achieve emission level targets in line with its Cancun pledges and NDC targets.

Recent independent studies (Kitous *et al.,* 2017; Kuramochi *et al.,* 2017a; CAT, 2018f) have revised their emissions projections down compared with previous years (UNEP, 2017), but do not strongly suggest that CO_2 emissions will peak before 2030. Contrastingly, other recent studies argue that recent structural shifts in the economy are likely to result in much steeper reductions in CO_2 intensity of Gross Domestic Product (GDP). Green and Stern (2017) provide an illustrative pathway in which intensity is halved from 2005 to 2020, resulting in peaked CO_2 emissions between 2020 and 2025. Guan *et al.* (2018) also conclude that the decline of CO_2 emissions in China is structural and is likely to be sustained if recently started transitions of industrial and energy systems continue.

China announced a new national emissions trading system in December 2017, which is expected to be fully operational by 2020. Initially, the system will apply only to the power sector, but may be expanded to other sectors in the future. The system's overall impact on CO_2 emissions is currently unclear, as many operational details are yet to be shared, including the start date and the level and distribution of emissions allowances. It is estimated that the full scheme will cover 5 $GtCO_2$/year when it includes both the power and industrial sectors, and 3–3.5 $GtCO_2$/year when only applied to the power sector as planned for the first few years (NewClimate

Institute, PBL and IIASA, 2018). Further features of China's national emissions trading system are described in Jotzo *et al.* (2018). The National Development and Reform Commission announced it will reduce steel capacity by around 30 million tonnes and coal output by about 150 million tonnes in 2018, thus achieving its Five-Year Plan targets ahead of the original target year 2020.

In its Cancun pledge, the **EU28** committed to reducing GHG emissions by 20 percent below 1990 levels by 2020, which it is expected to overachieve. In its NDC, the EU has put forward a binding, economy-wide target of reducing domestic GHG emissions by 40 percent below 1990 levels by 2030. Recent independent studies, including (CAT, 2018g), the European Environment Agency Trends and Projections Report (European Environment Agency, 2017) and the EU Reference Scenario (European Commission, 2016b), suggest that the EU will fall slightly short of its NDC target under existing policies. The EU recognizes that it is not on track to meet its 2030 target with current policies and has adopted a large package of measures aimed at accelerating the reduction of GHG emissions in different areas. The impact of these adopted measures is not included in the analysis of the studies cited above. More specifically, the revision of the EU Emissions Trading System (EU ETS) for 2021–2030 was adopted in March 2018, encompassing 3 key elements: (1) reducing the cap at an annual rate of 2.2 percent from 2021 onwards; (2) doubling the Market Stability Reserve feeding rate between 2019 and 2023 to reduce surplus of allowances; and (3) invalidating allowances in the Market Stability Reserve exceeding the number of allowances auctioned in the previous year from 2023 onwards (Council of the European Union, 2017b). The provisionally agreed Effort Sharing Regulation applying to GHG emissions from sectors not covered by EU ETS (transport, buildings, agriculture and waste management) was adopted in May 2018. The overall targeted reduction in GHG emissions from these sectors is 30 percent by 2030, relative to 2005, which is to be achieved by legally binding annual emission limits for each Member State for the 2021–2030 period (Council of the European Union, 2017c). The EU has also adopted a regulation to integrate GHG emissions and removals from LULUCF into the 2030 climate and energy framework (European Parliament, 2018) and proposals to amend the Energy Efficiency Directive and the Energy Performance of Buildings Directive (European Commission, 2016a; Council of the European Union, 2017a). By June 2018, the Governance of the Energy Union Regulation was agreed, which sets out the trajectory and interim targets for achieving the recently agreed 2030 goals of 32 percent renewable energy and 32.5 percent energy savings and requirements for regular progress reports.

India's Cancun pledge aims to reduce the emissions intensity of its Gross Domestic Product (GDP) by 20–25 percent below 2005 levels in 2020. In its NDC, India commits to reducing its emissions intensity of Gross Domestic Product (GDP) by 33–35 percent below 2005 levels by 2030, increasing the share of non-fossil energy in total power generation capacity to 40 percent (with help of international support), and creating an additional cumulative carbon sink of 2.5–3 $GtCO_2e$ through forest and tree cover. These translate into emission levels of 4.4–7.5 $GtCO_2e$/year and 4.2–5.9 $GtCO_2e$/year in 2030 for the unconditional and conditional NDCs respectively. With its currently implemented policies, India is likely to achieve its Cancun pledge and conditional NDC targets (IEA, 2017; Kitous *et al.*, 2017; Kuramochi *et al.*, 2017a; Mitra *et al.*, 2017; PBL, 2017; Vishwanathan and Garg, 2017; CAT, 2018h; Dubash *et al.*, 2018). Dubash *et al.* (2018) reviewed several studies and found that India's NDC intensity pledge is consistent with current (circa 2015) policies. Recent analysis by The Energy and Resources Institute (TERI) (COMMIT, 2018) indicates that India is also likely to meet and even overachieve its emissions intensity reduction target.

Several recently proposed initiatives have the potential to contribute significantly towards this target. Of major relevance are the actions that are likely to be undertaken under the National Solar Mission, the programmes implemented under the National Mission for Enhanced Energy Efficiency such as the Perform, Achieve and Trade scheme and the Standards and Labelling scheme, and the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles initiative adopted in April 2018. However, there are considerable uncertainties regarding the scale and pace of adopting various technologies such as electric vehicles and renewable-based power generation. The scale-up and adoption of these options depends on how quickly technology and battery costs can attain commercial viability and become the preferred alternatives.

In its Cancun pledge, **Indonesia** pledges an unconditional 26 percent and a conditional 41 percent reduction below business as usual GHG emissions by 2020. Similarly, its NDC sets an unconditional 29 percent and a conditional 41 percent (with sufficient international support) reduction target below business as usual for GHG emissions by 2030. The NDC includes emissions from deforestation and peat land destruction, which are the country's largest sources of GHG emissions. There is large uncertainty on the GHG emission level of Indonesia's Cancun pledge due to the business as usual emission data used. Studies, including those recently published (Kitous *et al.*, 2017; Kuramochi *et al.*, 2017; CAT 2018) do not agree on whether the Cancun pledge and NDC targets are likely to be met under policies currently implemented. Two recent studies (Kitous *et al.*, 2017; CAT 2018i), both excluding LULUCF, suggest that the conditional NDC may be achieved, while Kuramochi *et al.* (2017) project that Indonesia will fall short of achieving its Cancun pledge and unconditional NDC target, partially due to large growth in emissions from LULUCF.

Japan is committed to reducing its GHG emissions by 3.8 percent below 2005 levels by 2020 and 26 percent below 2013 levels by 2030. Recent studies (Kitous *et al.*, 2017) project that Japan will overachieve its 2020 pledge due to low growth in electricity demand since 2012. Japan may reach its 2030 NDC target with existing policies, but uncertainty over future nuclear and coal power remains (CAT, 2018g). Compared with previous year's projections, the 2017 update from the EU Joint Research Centre (JRC) (Kitous *et al.*, 2017) projected 7.5

percent lower emissions in 2030, while latest projections from the Climate Action Tracker only changed marginally (CAT, 2018g).

In July 2018, the new Basic Energy Plan was adopted by the Cabinet (METI, 2018). While the plan did not revise the electricity mix target underlying the NDC, it now refers to renewables as 'main power sources' of the future, which suggests a positive policy shift from the 2014 plan. Another positive sign from the new Basic Energy Plan is that for the first time it mentions phasing-out old, inefficient coal-fired power plants, though it continues to promote high-efficiency coal-fired power plants.

Mexico's NDC makes an unconditional commitment to reduce GHG emissions by 22 percent below business as usual in 2030, implying a net emissions peak from 2026, and a conditional commitment to reduce emissions by 36 percent below business as usual in 2030. Mexico's NDC also addresses black carbon emissions (UNFCCC, 2015). Studies disagree on whether Mexico is likely to meet its 2020 pledge (30 percent below business as usual) or NDC targets under current policies (Kuramochi *et al.,* 2017a; CAT, 2018j). Recent Climate Action Tracker projections for 2030 are 1–4 percent lower than levels projected a year ago (CAT, 2018j).

By the end of 2017, Mexico's National Institute of Ecology and Climate Change (INECC) had assessed the advancement of the Special Climate Change Program 2013–2018 (PECC by its Spanish acronym), which is the Mexican federal administration's instrument for climate action. The assessment noted that only 43 percent of the programmed climate actions for the 2013–2018 period were completed (INECC, 2017) and that they reduced emissions by 30 $MtCO_2e$, a third of what the government expected for the period. Furthermore, there are no mechanisms in place to effectively monitor mitigation actions of subnational governments and private sector companies, hindering the tracking of the climate efforts.

Mexico updated its General Climate Change Law in late 2017 to create a mandatory carbon market from 2018 with a 3 year pilot phase (Secretaría de Medio Ambiente y Recursos Naturales, 2017). Moreover, the update also incorporated a mandate for the country to contribute to the fulfilment of the Paris Agreement.

The new federal government (2018–2024) has recognized the importance of the Paris Agreement and of increasing the proportion of renewable energy in the electricity mix. However, tensions are anticipated between the energy outlook (with a significant share of fossil fuels) and the expected emission reduction targets which will increase the NDC ambition.

In its NDC, the **Republic of Korea** has committed to reducing its GHG emissions by 37 percent below business as usual by 2030 (Ministry of Environment, 2018). The Government of Korea set up a road map in 2016 to achieve the national GHG emissions reduction target for 2030, which specifies emissions projections, reduction targets and major emission reduction plans for 8 sectors (Government of the Republic of Korea, 2017), though there is limited information about the implementation status of these sector-level plans.

In June 2018, the road map was amended to reduce reliance on overseas credits from 11.3 percent to 4.5 percent (Ministry of Environment, 2018). Recent independent analyses (CAT, 2017a; PBL, 2017) indicate that the emission projections under current policies may fall short of the NDC emission level target. While the country has not rescinded its pledge to the UNFCCC for 2020, it has amended its Green Growth Basic Act to replace the 2020 pledge with the NDC target for 2030 (National Law Information Center, 2016).

In 2017, President Moon Jae-in announced that the Republic of Korea will reduce its dependency on coal-fired and nuclear power generation (Cheong Wa Dae, 2017; MOTIE, MOE and MOLIT, 2017), while increasing renewable electricity. Following this, the government adopted a new Basic Plan for Long-Term Electricity Supply and Demand covering the next 15 years, confirming the country intends to produce more electricity from renewable energy sources, while reducing its use of coal and nuclear power (CAT, 2018n; Ministry of Trade, Industry and Energy, 2018). This plan may result in an electricity generation mix in 2030 that is 23.9 percent nuclear, 36.1 percent coal, 18.8 percent natural gas and 20 percent renewable energy. Analysis indicates that these announcements, if fully implemented, together with the expected lower level of electricity demand, may lead to reductions of 53–69 $MtCO_2e$/year (7–9 percent) below current policies scenario projections in 2030. However, this is not enough for the country to achieve its NDC target (CAT, 2018n).

Russia pledged to limit GHG emissions by 15–25 percent below 1990 levels by 2020 and proposed in its Intended Nationally Determined Contribution (INDC) to reduce GHG emissions by 25–30 percent below 1990 levels by 2030. Although Russia has reaffirmed its 2020 target in subsequently adopted policies, it had not ratified the Paris Agreement as at August 2018 and is the only major emitter that has not done so. While accounting of emissions from LULUCF remains unclear, provisions in the INDC suggest that its target includes these emissions. Recently published studies (Kuramochi *et al.,* 2017a; CAT, 2018k) suggest that under current policies, Russia is likely to meet its 2020 pledge and reach the lower end of its 2030 INDC range. In July 2017, the Government of Russia introduced a plan to reform all existing federal laws concerning energy generation facilities to include renewable energy microgeneration for facilities with installed capacity up to 15 kW (Government of Russia, 2017; Ministry of Environment and Natural Resources, 2017).

In its NDC, **Saudi Arabia** commits to reducing emissions by up to 130 $MtCO_2e$/year by 2030 through actions that contribute to economic diversification and adaptation. The baseline for this NDC target has not been communicated as at August 2018, due to unresolved questions on the allocation of oil production to domestic consumption or export. Under current policies, Saudi Arabia is expected to achieve GHG emission levels of 1,115–1,175 $MtCO_2e$/year by 2030 (CAT, 2018l). According to these projections, Saudi Arabia will clearly miss its NDC emissions levels of 940–1,120 $MtCO_2e$/year by 2030, quantified using a baseline range (the lower end based on European Commission's Joint Research Center and the upper end based on King Abdullah University of Science and Technology (KAUST) (2014), see Kuramochi *et al.* (2017a)). Starting in January 2018, Saudi Arabia implemented an economy-wide 5 percent VAT on fossil fuels (Nereim, 2017). However, the government announced a delay in fossil fuel price reforms in December 2017 by slowing down the pace of energy subsidy cuts (Toumi, 2017).

In its Cancun pledge, **South Africa** aims to reduce its GHG emissions by 34 percent below business as usual in 2020 and in its NDC commits to achieving a "peak, plateau and decline" of greenhouse emissions, peaking between 2020 and 2025 and plateauing at 398–614 $MtCO_2e$/year between 2025 and 2030. Recently published studies (Kitous *et al.,* 2017; Kuramochi *et al.,* 2017a; CAT, 2018m) indicate that under current policies, South Africa may just meet the upper end of its Cancun pledge range, but will miss its NDC target by emitting 650–770 $MtCO_2e$/year in 2030. In February 2018, the proposed Carbon Tax Bill entered the parliamentary process after 2 years of consultations. After further parliamentary hearings and revisions, the final draft was expected to be completed by mid-2018 (EY, 2017; Republic of South Africa, 2017; Ensor, 2018), though it is yet to be released. The Department of Energy released its update of the Integrated Resource Plan (IRP) (Department of Energy, 2018) on future energy supply planning in August 2018 for public comments until November 2018. The plan's update proposes to decommission 12 GW of old coal power plants by 2030, while increasing gas, wind and solar generation capacity. First estimates suggest that the proposed update, if implemented, would allow South Africa to meet the upper range of its NDC target by 2030 (CAT, 2018m).

Turkey submitted its INDC on 30 September 2015, with a target to reduce GHG emissions up to 21 percent below business as usual in 2030 (Republic of Turkey Ministry of Environment and Urbanization, 2016). With currently implemented policies, Turkey is expected to achieve GHG emission levels of 959–1,075 $MtCO_2e$/year in 2030 (excluding LULUCF). The lower estimate is based on both planned and current policies. According to an independent analysis based on government projections, current policies are insufficient to meet Turkey's INDC and the country has an ongoing investment in expanding coal power production (CAT, 2017b).

The **United States of America** set a 2020 target to reduce GHG emissions by 17 percent below 2005 levels in 2020 (UNFCCC, 2014) and committed to reducing emissions by 26-28 percent below 2005 levels by 2025 in its NDC (UNFCCC, 2016). However, under President Donald Trump, the USA has communicated its intent to withdraw from the Paris Agreement, unless it can identify suitable terms for reengagement, and to cease implementation of its NDC (The Representative of the United States of America to the United Nations, 2017). In October 2017, the US Environmental Protection Agency (EPA) proposed to repeal the Clean Power Plan (US EPA, 2017), which would have required states to meet CO_2 emission standards for electricity generation. In April 2018, EPA announced that it would revise GHG emission standards for cars and light trucks (US EPA, 2018). 17 states led by California have filed a lawsuit to prevent these rollbacks (State of California, 2018). In January 2018, the USA increased tariffs on imported solar cells and modules by 30 percent (The Executive Office of the President 2018).

Under currently implemented policies, the USA is unlikely to meet its NDC target for 2025 and it is uncertain whether it will meet its 2020 target (Kuramochi *et al.,* 2017b; CAT, 2018o; Larsen *et al.,* 2018), though action by non-state and subnational actors in the country could contribute significantly to reducing future emissions (Kuramochi *et al.,* 2017c). A range of studies find that given policy rollbacks, GHG emissions in 2025 will be between 0.8–1.9 $GtCO_2e$/year higher than had the NDC been achieved (Fransen and Levin, 2017). However, despite federal efforts to weaken emission standards and other policies, recent analysis projects that GHG emissions in 2030 will be 3–8 percent lower than projections made in 2017 (Kitous *et al.,* 2017; Kuramochi *et al.,* 2017a; PBL, 2017; *CAT, 2018o*), partially due to a higher projected share of gas and renewables in electricity generation (U.S. Energy Information Administration, 2018). There will be a time lag between policy rollbacks and their impact on emission levels.

Chapter 3.
The emissions gap

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3.1 Introduction

This chapter presents an update of the emissions gap in 2030. In line with previous reports, the emissions gap is defined as the difference between where global greenhouse gas (GHG) emissions are heading under the current Nationally Determined Contributions (NDCs) and where science indicates emissions should be in 2030 to be on a least-cost path towards limiting warming to below 2°C or further to 1.5°C. The 2018 assessment draws on several new studies that present updated NDC estimates and additional low emission scenarios in line with achieving the climate objective of the Paris Agreement.

The chapter starts with an introduction to the scenarios that have been used and the updates made (section 3.2). This is followed by an updated assessment of the emissions gap in 2030 (section 3.3), which builds on an updated assessment of emission levels in 2030, under current policies, NDCs and emission levels consistent with least-cost mitigation pathways to below 2°C to 1.5°C. The chapter then provides an update on the implications of temperatures projections anticipated under current NDCs (section 3.4), concluding with an analysis of the effects of higher or lower emissions in 2030 (section 3.5)

3.2 Scenarios considered and updates made

The emissions gap assessment draws on three main types of scenarios of total global GHG emissions in the future: reference scenarios, NDC scenarios and least-cost mitigation scenarios consistent with specific temperature targets (see UNEP, 2016, 2017). Each of these scenarios and the updates made since the 2017 Emissions Gap Report are described below.

3.2.1 Reference scenarios and updates

Reference scenarios are useful benchmarks against which progress in emission reductions can be tracked. Two reference scenarios are considered: the no-policy baseline and current policy scenarios. The *no-policy baseline scenario* explores the trend of global GHG emissions in the absence of climate policies post-2005. It is based on mean projections of 179 baseline scenarios assessed in the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Clarke *et al.*, 2014). Recently, new no-policy baselines have been published, though these have not resulted in significant changes to the no-policy baseline scenario estimates (Riahi *et al.*, 2017; Luderer *et al.*, 2018).

The *current policy scenario* estimates future global GHG emissions, assuming that all currently adopted and implemented policies (defined as legislative decisions, executive orders or equivalent) have been realized and that no additional measures are to be undertaken. The scenario is based on the country analyses in chapter 2 and updated global analyses that use new data from eight modelling groups. These include updated analyses from the four modelling groups considered in the 2017 Emissions Gap Report (UNEP, 2017), namely, the Climate Action Tracker (CAT, 2018), the Joint Research Centre (Kitous *et al.*, 2017), PBL Netherlands Environmental Assessment Agency (Kuramochi *et al.*, 2017; PBL, 2018) and the International Energy Agency (IEA, 2017).

3.2.2 NDC scenarios and updates

NDC scenarios are used to estimate what the total global GHG emissions would be in 2030 if countries fully implemented their pledged contributions. Following previous Emissions Gap Reports, two NDC scenarios are considered: the unconditional and conditional NDC scenarios.

Under the *unconditional NDC scenario*, it is assumed that countries only implement mitigation-related actions of their NDCs that have no conditions attached. Countries that do not have an NDC or have only included a conditional target are assumed to follow a current policy scenario instead. Under the *conditional NDC scenario*, it is assumed that countries implement both conditional and unconditional mitigation actions of their NDCs. Countries without an NDC are assumed to follow a current policy scenario and those without a conditional target follow the unconditional scenario.

Global emission projections from 15 modelling groups are considered for the two NDC scenarios. These projections include five new model estimates with full GHG coverage and 10 modelling groups from the 2017 Emissions Gap Report (UNEP, 2017). Appendix A.1, which is available online, provides a full overview of the studies considered for the current policy and NDC scenarios.

3.2.3 Least-cost mitigation scenarios consistent with the Paris Agreement's temperature limits and updates following the IPCC Special Report on Global Warming of 1.5°C

Compared with previous Emissions Gap Reports, two major changes have been made to the 2018 assessment of global GHG emission levels in 2030 that are in line with least-cost pathways to limit warming to below 2°C or 1.5°C. As section 3.3 shows, these updates have implications for the estimated emissions gap in 2030, particularly for the 1.5°C target.

The 2018 assessment builds on the new scenario database compiled in the context of the IPCC Special Report on Global Warming of 1.5°C (Huppmann *et al.*, 2018a, 2018b). Whereas 16 scenarios were available in 2017, 85 scenarios for 1.5°C and 2°C pathways are available this year.[1] This expansion has enhanced the diversity of available scenarios that are consistent with the stringent temperature goal of the Paris Agreement. In particular, recent scenarios often set a lower maximum potential for carbon dioxide removal (CDR), which results in deeper emissions reductions over the next decades to stay within the same overall carbon budget (see section 3.5.1)[2].

The second major update concerns the method for grouping pathways. Previous Emissions Gap Reports used a simple climate model to estimate the temperature outcome of pathways, which were then used to group and describe various pathway classes. This year's assessment still groups pathways as a function of their estimated temperature outcome, but uses the pathways' cumulative CO_2 emissions as a simpler proxy. The rationale behind this is that a nearly linear relationship exists between the total amount of anthropogenic CO_2 emissions released into the atmosphere and the increase in global mean temperature (Allen *et al.*, 2009; Matthews *et al.*, 2009; Meinshausen *et al.*, 2009; Zickfeld *et al.*, 2009; Collins *et al.*, 2013. See also UNEP, 2014), meaning that warming under a specific future pathway can be estimated from its cumulative CO_2 emissions. Alternatively, if a certain temperature limit is set, a corresponding consistent carbon (CO_2) budget can be calculated. The linear relationship also implies that CO_2 emissions need to become net zero at the global scale if warming is to be kept below any level (Matthews *et al.*, 2012; Knutti and Rogelj, 2015). Achieving global net zero emissions means that CDR will compensate for any remaining human-related CO_2 emissions.

The use of the cumulative CO_2 emission proxy for grouping pathways has the advantage of linking more directly to the discussions on emissions pathways under the United Nations Framework Convention on Climate Change (UNFCCC). It also facilitates future updates and improvements in understanding how the climate responds to anthropogenic GHG emissions.

Based on these updates, pathways are grouped in *three temperature scenario groups*, according to their maximum cumulative CO_2 emissions from 2018 onwards. These three scenario groups provide a more nuanced overview of pathways that keep warming below 2°C to 1.5°C and also help to identify the consequences of strengthened action at various degrees of ambition: from limiting warming to 2°C, over potential interpretations of 'well below 2°C', to pursuits to limit warming to 1.5°C and the corresponding emission reductions (see table 3.1). Each scenario considers least-cost climate change mitigation pathways that start reductions from 2020 and follow the climate model and set-up used in the IPCC 5th Assessment Report (see box 3.1).

- *Below 2°C scenario:* This scenario limits maximum cumulative CO_2 emissions from 2018 until the time net zero CO_2 emissions are reached (or until 2100 if net -zero is not reached before) to between 900 and 1,300 $GtCO_2$, and cumulative 2018-2100 emissions to at most 1,200 $GtCO_2$. It is consistent with limiting end-of-century warming to below about 2.0°C with about 66 percent or greater probability, while limiting peak global warming during the 21st century to below 2.1°C with about 66 percent or greater probability.
- *Below 1.8°C scenario:* This scenario limits maximum cumulative CO_2 emissions from 2018 until the time net zero CO_2 emissions are reached (or until 2100 if net-zero is not reached before) to between 600 and 900 $GtCO_2$, and cumulative 2018-2100 emissions to at most 900 $GtCO_2$. It is consistent with limiting peak and end-of-century warming to below about 1.8°C with about 66 percent or greater probability.
- *Below 1.5°C in 2100 scenario:* This scenario limits maximum cumulative CO_2 emissions from 2018 until the time net zero CO_2 emissions are reached (all model realizations in this scenario reach net zero before 2100) to below 600 $GtCO_2$, and cumulative 2018-2100 emissions to at most 380 $GtCO_2$, when net negative CO_2 emissions in the second half of the century are included. It is consistent with limiting global warming to below 1.5°C in 2100 with about 66 percent probability, while limiting peak global warming during the 21st century to between 1.6°C and 1.7°C with about 66 percent or greater probability. This scenario group is consistent with scenarios in the IPCC Special Report that limit warming to 1.5°C with no or limited overshoot.

1 These include several model-intercomparison studies from the ADVANCE project (Luderer *et al.*, 2018; Vrontisi *et al.*, 2018), CD-LINKS (McCollum *et al.*, 2018), EMF-33 (Bauer *et al.*, 2018) and Shared Socioeconomic Pathways (SSPs) (Riahi *et al.*, 2017; Rogelj *et al.*, 2018), as well as a number of individual model studies focusing on various aspects of climate stabilization in the 1.5°C to 2°C range (Bertram *et al.*, 2018; Grubler *et al.*, 2018; Holz *et al.*, 2018; Kriegler *et al.*, 2018; Strefler *et al.*, 2018; van Vuuren *et al.*, 2018).

2 For more information, see the Summary for Policymakers of the IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018).

Box 3.1 Uncertainties surrounding carbon budgets and corresponding temperature limits

Carbon budgets in line with a specific temperature limit have an uncertainty range to which various factors contribute, including the proportionality factor between cumulative CO_2 emissions and the increase in global mean temperature (Gillett *et al.*, 2013; Matthews *et al.*, 2017) and the contribution of non-CO_2 forcers (Rogelj *et al.*, 2016b). Due to this, IPCC's 5th Assessment Report (IPCC, 2014) indicated a variation in the carbon budget (from 1870 onwards) for limiting warming to 2°C of about 1,250 $GtCO_2$ (range of 33–66 percent, with a median estimate of slightly above 3,000 $GtCO_2$). As past and ongoing emissions continue reducing the remaining carbon budget, these uncertainties become more important in relative terms (Peters, 2018).

Recent studies have attempted to reduce these uncertainties, for example, by using a more recent reference period to express carbon budget estimates, such as 2006–2015 instead of pre-industrial times (see, for example, Millar *et al.*, 2017; Tokarska and Gillett, 2018). Although this approach eliminates some uncertainties that have accumulated over the historical period, it comes with caveats and limitations, which result in higher carbon budgets compared with estimated provided in the IPCC 5th Assessment Report (Pfleiderer *et al.*, 2018). The choice of method to estimate warming until the present is an important contributor to these higher budget estimates. Recent research also showed that Earth system feedbacks could cause additional warming, both during (Comyn-Platt *et al.*, 2018; Lowe *et al.*, 2018) and beyond the 21st century (Fischer *et al.*, 2018). This new literature on additional feedbacks therefore suggests that carbon budgets consistent with warming of 1.5°C or 2°C may be approximately 100 $GtCO_2$ smaller.

Although this report groups scenarios based on their cumulative CO_2 emissions, it also uses the climate model and set-up used in the IPCC 5th Assessment Report (Meinshausen *et al.*, 2011; Clarke *et al.*, 2014) for comparability with earlier reports.

Box 3.2 Technical comparison with the IPCC Special Report on Global Warming of 1.5°C

The analysis included in this chapter is consistent with the latest assessment of the IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018). The range of Kyoto-GHG emissions in 2030 consistent with limiting warming to 1.5°C used in this report (24 $GtCO_2e$/year with a range of 22–30 $GtCO_2e$/year) is consistent with the 25–30 $GtCO_2e$/year range reported in the recent IPCC Special Report (IPCC, 2018) for scenarios limiting global warming to 1.5°C with no or limited overshoot. Differences are attributed to the exclusive use of scenarios that start emissions reductions from 2020 onwards in this report, compared with a wider set in the IPCC Special Report. Overall, these minor changes do not affect the assessment of the adequacy of current NDCs for limiting warming to 1.5°C or well below 2°C.

From 2018 to the time of reaching net zero, the below 1.5°C by 2100 scenario has cumulative CO_2 emissions of less than 600 $GtCO_2$. This broadly corresponds to the remaining carbon budget for limiting warming to 1.5°C with 50 percent probability (580 $GtCO_2$ from 2018 to the time of reaching net zero) of the IPCC Special Report, limiting temperature overshoot to less than 0.1°C. Cumulative CO_2 emissions until the end of the century for any available below 1.5°C by 2100 scenario are at most 380 $GtCO_2$, which is less than the remaining carbon budget of 420 $GtCO_2$ for limiting warming to 1.5°C with 66 percent probability of the IPCC Special Report. Maximum cumulative CO_2 emissions for the below 1.8°C scenario are 900 $GtCO_2$ from 2018 to the time of reaching net zero. Using the IPCC Special Report assessment, this 900 $GtCO_2$ equates to a 66 percent probability of limiting warming to about 1.8°C. This also corresponds to about a 50 percent probability of limiting warming to 1.7°C. For the below 2°C scenario, maximum cumulative CO_2 emissions from 2018 to the time of reaching net zero are 1,300 $GtCO_2$ and from 2018 to 2100 are 1,200 $GtCO_2$. Using the IPCC Special Report assessment, this 1,200 $GtCO_2$ equates to keeping warming below 2°C with at least 66 percent probability by 2100, though there is a slightly lower probability at peak warming during the century. This suggest that the probability of limiting warming to 1.9°C is about 50 percent.

3.3 The emissions gap in 2030

The emissions gap for 2030 is defined as the difference between global total GHG emissions from least-cost scenarios that are consistent with the 2°C and 1.5°C temperature limits and the estimated total global GHG emissions resulting from full implementation of NDCs. To allow for a more nuanced interpretation of the Paris Agreement's temperature targets, this assessment includes a below 1.8°C scenario. This section updates the gap based on estimated levels of GHG emissions in 2030 for the scenarios described in section 3.2. Table 3.1 provides a full overview of 2030 emission levels for all seven scenarios considered in this assessment, as well as the resulting emissions gap. Figure 3.1 illustrates the emissions gap in 2030.

Table 3.1 indicates that in the absence of further climate action since 2005, that is, under a *no-policy baseline scenario*, the total global GHG emissions in 2030 would be 65 $GtCO_2e$ (range of 60–70 $GtCO_2e$). *Current policies* are estimated to reduce global emissions in 2030 by around 6 $GtCO_2e$ compared with the no-policy scenario. There are no substantive updates to these estimates compared with the 2017 assessment. The median current policy estimate for 2018 is roughly 0.5 $GtCO_2e$ lower than the 2017 estimate, which is within rounding precision. The lower and upper limit of the range for the current policy estimate has decreased by 2 $GtCO_2e$ and 1 $GtCO_2e$ respectively due to lower projections (see chapter 2, section 2.4). Overall, this implies that studies have not identified significant and unambiguous progress in the implementation of policies that would allow the NDCs to be achieved by 2030. However, the estimates of global emissions in 2030 under the current policy scenario have decreased slightly since 2015, from 60 $GtCO_2e$ (range of 58–62 $GtCO_2e$) (UNEP, 2015) to 59 $GtCO_2e$ (range of 56–60 $GtCO_2e$) in 2018, indicating that some studies show slight progress in policy implementation since the adoption of the Paris Agreement.

Table 3.1: Total global greenhouse gas emissions in 2030 under different scenarios (median and 10th to 90th percentile range), temperature implications and the resulting emissions gap.

Scenario (rounded to the nearest gigatonne)	Number of scenarios in set	Global total emissions in 2030 [$GtCO_2e$]	Estimated temperature outcomes			Emissions Gap in 2030 [$GtCO_2e$]		
			50% chance	66% chance	90% chance	Below 2°C	Below 1.8°C	Below 1.5°C in 2100
No-policy baseline	179	65 (60–70)						
Current policy	4	59 (56–60)				18 (16–20)	24 (22–25)	35 (32–36)
Unconditional NDCs	12	56 (52–58)				15 (12–17)	21 (17–23)	32 (28–34)
Conditional NDCs	10	53 (49–55)				13 (9–15)	19 (15–20)	29 (26–31)
Below 2.0°C (66% chance)	29	40 (38–45)	Peak: 1.7–1.8°C In 2100: 1.6–1.7°C	**Peak: 1.9–2.0°C** **In 2100: 1.8–1.9°C**	Peak: 2.4–2.6°C In 2100: 2.3–2.5°C			
Below 1.8°C (66% chance)	43	34 (30–40)	Peak: 1.6–1.7°C In 2100: 1.3–1.6°C	**Peak: 1.7–1.8°C** **In 2100: 1.5–1.7°C**	Peak: 2.1–2.3°C In 2100: 1.9–2.2°C			
Below 1.5°C in 2100 (66% chance)	13	24 (22–30)	Peak: 1.5–1.6°C In 2100: 1.2–1.3°C	**Peak: 1.6–1.7°C** **In 2100: 1.4–1.5°C**	Peak: 2.0–2.1°C In 2100: 1.8–1.9°C			

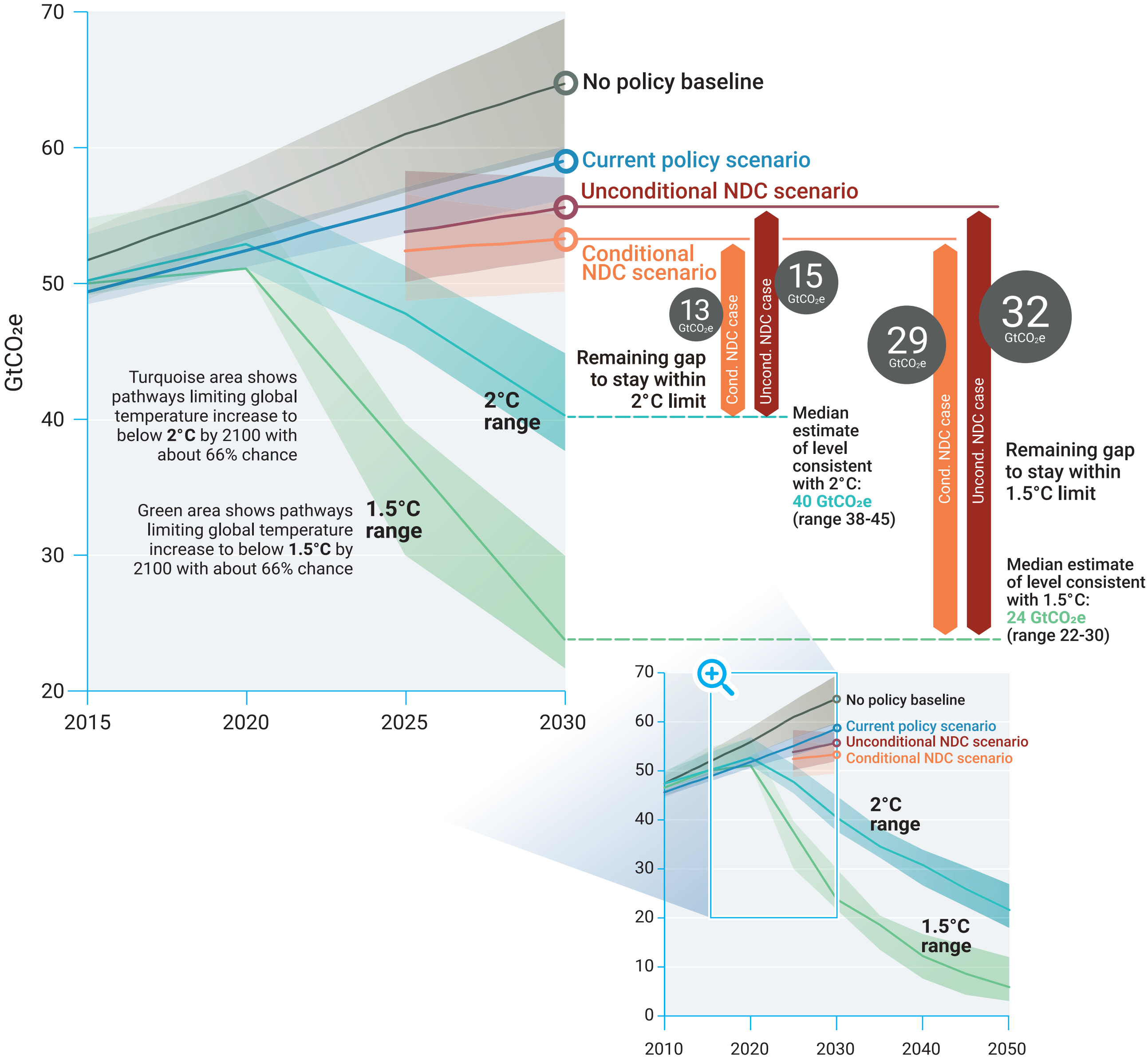
Note: The gap numbers and ranges are calculated based on the original numbers (without rounding), which may differ from the rounded numbers (3rd column) in the table. Numbers are rounded to full $GtCO_2e$. GHG emissions have been aggregated with 100-year global warming potential values of the IPCC 2nd Assessment Report. The NDC and current policy emission projections may differ slightly from the presented numbers in Cross-Chapter box 11 of the IPCC Special Report (Bertoldi *et al.*, 2018) due to the inclusion of new studies after the literature cut-off date set by the IPCC. Pathways were grouped in three categories depending on whether their maximum cumulative CO_2 emissions were less than 600 $GtCO_2$, between 600 and 900 $GtCO_2$, or between 900 and 1,300 $GtCO_2$ from 2018 onwards until net zero CO_2 emissions are reached, or until the end of the century if net zero is not reached before. Pathways assume limited action until 2020 and cost-optimal mitigation thereafter. Estimated temperature outcomes are based on the method used in the IPCC 5th Assessment Report.

Full implementation of the unconditional and conditional NDCs is estimated to reduce global emissions in 2030 by about 3 $GtCO_2e$ and 6 $GtCO_2e$ respectively, compared with the current policy scenario (table 3.1). Some of the new studies included in this year's assessment have higher NDC estimates, resulting in a slight increase of 1 $GtCO_2e$ in the median unconditional NDC estimate and an increase in the upper end of the range for the unconditional and conditional NDC estimates by 2 $GtCO_2e$ and 1 $GtCO_2e$ respectively.

Studies underlying the current policy trajectory scenario and the NDC scenario differ in various ways, such as their treatment of conditional versus unconditional NDCs and their assumptions regarding non-covered sectors and gases. These methodological differences cannot be fully harmonized, which leads to some uncertainty as indicated by the ranges around the median estimates (see table 3.1 and online appendix A.1). These differences and their implications are further described in online appendix A.2 and in the 2016 Emissions Gap Report (UNEP, 2016), which also provides a more complete discussion of the different types of scenarios.

The major change compared with the 2017 Emissions Gap Report is in the assessment of 2030 GHG emission levels consistent with limiting global warming to below 2°C and lower. As discussed in section 3.2, the 2018 assessment draws on numerous new 1.5°C and 2°C-consistent least-cost emissions pathways that have become available in the context of the IPCC Special Report (Huppmann *et al.*, 2018a, 2018b). Furthermore, the assessment adopts a new methodology, which groups pathways under three temperature scenarios based on their cumulative CO_2 emissions. These updates result in target emission levels for 2030 that

Figure 3.1: Global greenhouse gas emissions under different scenarios and the emissions gap in 2030 (median estimate and 10th to 90th percentile range).



differ from the ranges assessed in the 2017 report. Table 3.1 shows that in the below 2.0°C scenario (about 66 percent probability), which is consistent with maximum cumulative emissions of 900–1,300 $GtCO_2$, GHG emission levels for 2030 are 40 $GtCO_2e$ (range of 38–45 $GtCO_2e$). This is around 2 $GtCO_2e$ lower than 2017 estimates but well within the reported uncertainty range. For pathways with maximum cumulative emissions of 600–900 $GtCO_2$, which is consistent with keeping global warming below 1.8°C with about 66 percent probability, GHG emission levels for 2030 are 34 $GtCO_2e$ (range of 30–40 $GtCO_2e$). For the below 1.5°C in 2100 scenario, based on pathways where cumulated maximum CO_2 emissions from 2018 are below 600 $GtCO_2$, emission levels in 2030 are as low as 24 $GtCO_2e$ (range of 22–30 $GtCO_2e$). This is 12 $GtCO_2e$ lower than the estimate in 2017 of 36 $GtCO_2e$ (range of 32–38 $GtCO_2e$), mainly because many recent studies assume that less negative emissions will be available over the course of this century, thus requiring steeper emission reductions in the next decades to keep peak warming as low as possible. The inclusion of pathways consistent with keeping global warming to below 1.8°C, combined with the indication of temperature outcomes for about a 50 percent, 90 percent and 66 percent probability, allow for a more nuanced interpretation and discussion of what 'well below 2°C' means and implies in terms of emission reductions required.

The emissions gap between estimated total global emissions in 2030 under the NDC scenarios and pathways limiting warming to below 2°C and 1.5°C is illustrated in figure 3.1, where the no-policy and current policy scenarios are also included. Full implementation of unconditional NDCs is estimated to result in a gap of 15 $GtCO_2e$ (range of 12–17 $GtCO_2e$) in 2030 compared with the below 2°C scenario. This is about 2 $GtCO_2e$ higher than the gap assessed in the 2017 report, due to the lower 2°C scenario estimate. If the conditional NDCs are also fully implemented, the gap reduces by about 2 $GtCO_2e$. The emissions gap between unconditional NDCs and below 1.5°C pathways is about 32 $GtCO_2e$ (range of 28–34 $GtCO_2e$). This is about 13 $GtCO_2e$ higher than assessed in the 2017 report, due to the lower 1.5°C scenario estimates as explained above. Considering the full implementation of both unconditional and conditional NDCs would reduce this gap by roughly 3 $GtCO_2e$.

In summary, the assessment amplifies concerns regarding both ambition and action compared with previous Emissions Gap Reports. According to the current policy and NDC scenarios, global emissions are not estimated to peak by 2030, let alone by 2020. The NDCs are estimated to reduce global emissions in 2030 by a maximum 6 $GtCO_2e$ compared with a continuation of current policies. As the emissions gap assessment shows, reductions that are roughly 2 to 3 times higher are needed to bridge the gap between conditional NDCs and 2°C pathways, and five times higher to align emissions with 1.5°C pathways.

3.4 Temperature implications of the NDCs

The implications for global warming by the end of the century can be estimated based on the 2030 level of GHG emissions resulting from full implementation of the NDCs. The Emissions Gap Reports use a method that builds on information from scenarios available in the peer-reviewed literature. Such scenarios provide internally consistent long-term emission projections and relate 2030 GHG emission levels to temperature outcomes throughout the 21st century (Rogelj *et al.*, 2016a). The method used in these reports has been assessed in a recent study (Jeffery *et al.*, 2018) to provide consistent and useful results for a wide range of emissions reduction levels in 2030, in contrast to some of the other methods found in the literature consulted.

Assuming that climate action continues consistently throughout the 21st century, implementing the unconditional NDCs would lead to a mean global temperature of around 3.2°C (with a range of 2.9–3.4°C), relative to pre-industrial levels by 2100. Since these projections do not reach net zero CO_2 emissions by 2100, temperatures are further projected to increase thereafter. Full implementation of both unconditional and conditional NDCs would reduce these estimates by 0.2°C in 2100. These projections are identical to those made in 2017, within rounding precision.

3.5 Implications of 2030 emission levels

The large ranges in least-cost 2030 global GHG emissions reported in table 3.1 for limiting warming to below 2°C or 1.5°C not only reflect variations between models, but also differences in societal choices that should be made to achieve desired climate outcomes. Such outcomes may include deciding the degree to which it is acceptable to rely on large-scale CDR after 2050, how mitigation action should be spread over time or what an acceptable level of burden is for future generations. Recent studies allow these choices to be better understood by illustrating the implications associated with aiming to achieve the higher or lower end of the identified ranges, or with missing them altogether. The recently approved IPCC Special Report on Global Warming of 1.5°C points out that the global emissions outcome from the aggregate effect of the NDCs is too high to prevent exceedance of the 1.5°C threshold (IPCC, 2018; Rogelj *et al.*, 2018). Here, the focus is on implications of 2030 emission level choices for (1) the future reliance and scale of CDR; (2) the simultaneous achievement of other sustainability objectives; and (3) lock-in of carbon-intensive infrastructure that makes future emission reductions more difficult.

3.5.1 Limiting future reliance on carbon dioxide removal

Mitigation scenarios that stabilize global warming to well below 2°C or 1.5°C differ widely in their use of CDR (Rogelj *et al.*, 2018b), which is associated with several environmental and social sustainability risks (Smith *et al.*, 2016; Minx *et al.*, 2018). CDR of some form will likely be required for these warming limits, especially the 1.5°C goal, though its extent may vary (Rogelj *et al.*, 2015; Luderer *et al.*, 2018). A recent study (Strefler *et al.*, 2018) shows that strengthened action in the near future can significantly decrease CDR requirements for the remainder of the century. Reducing CO_2 emissions by 22–53 percent below current NDC levels in 2030, which would align emission levels with below 2°C and 1.5°C pathways, would substantially alleviate the trade-off between disruptive emission reduction requirements post-2030 and potentially unattainably and unsustainably high CDR deployment. The IPCC Special Report indicates that the CDR requirements to compensate for an overshoot of 0.2°C or larger during this century might not be achievable (IPCC, 2018). Furthermore, optimal 2030 GHG emission levels depend strongly on the availability of CDR: below 1.8°C and below 1.5°C pathways with limited CDR have 7–12 $GtCO_2e$ less 2030 GHG emissions than corresponding pathways with a full technology portfolio. The six 1.5°C pathways available from the literature that limit the availability of biomass with carbon capture and storage technologies (Bauer *et al.*, 2018; Bertram *et al.*, 2018; Grubler *et al.*, 2018; Holz *et al.*, 2018; Kriegler *et al.*, 2018; van Vuuren *et al.*, 2018) all have GHG emission levels of at most 25 $GtCO_2e$ in 2030.

3.5.2 Achieving sustainability

Numerous interactions and potential synergies and trade-offs between climate change mitigation and other sustainability objectives are highlighted in the recent literature (von Stechow *et al.*, 2015; 2016; Jakob and Steckel, 2016; UNEP, 2016; Bertram *et al.*, 2018; McCollum *et al.*, 2018). Broad societal choices and developments regarding lifestyles and socioeconomics will determine the feasibility and effort required to simultaneously achieve the Paris Agreement's objectives and the Sustainable Development Goals (Rogelj *et al.*, 2018a). The literature also shows that stronger near-term emission reductions have the potential to increase mitigation co-benefits in both the coming decade and later in the century, for example, through reduced air pollution, lower water demand and decreased dependence on bioenergy (Bertram *et al.*, 2018; IPCC, 2018). For instance, Rao *et al.* (2016) show that combining deep decarbonization with stringent air pollution control policies can decrease the share of global population exposed to high particulate matter concentrations from 21 percent to 3 percent in 2050. Markandya *et al.* (2018) estimate that air pollution-related mortality during the 2020–2050 period can be reduced by around one quarter compared with business as usual if CO_2 emission reductions are in line with the Paris Agreement targets. In addition, dedicated policies for differentiated carbon pricing or energy efficiency regulation have been identified to effectively mitigate potential adverse side effects, such as exceedingly large land requirements for bioenergy (Bertram *et al.*, 2018) or impacts of climate policies on food and energy prices (Fujimori *et al.*, 2018). Grubler *et al.* (2018) have shown that strong efforts towards improving energy efficiency lowers near-term GHG emissions, increases sustainability co-benefits and could keep the 1.5°C limit within reach with much lower CDR levels.

3.5.3 Avoiding lock-in of carbon-intensive infrastructure

Sociotechnical systems in general and energy systems in particular are characterized by inertia and path dependency due to long-lived capital stocks with slow turnover, infrastructure requirements, learning by doing and cultural practices. As noted in previous Emissions Gap Reports, these inertias give rise to the notion of carbon lock-in, which is large-scale committed emissions resulting from existing infrastructures (see also Unruh, 2000; Davis *et al.*, 2010). The scenario literature clearly demonstrates that weak near-term climate policy ambition increases the long-term emissions commitment from fossil-based infrastructures, decreases the economic mitigation potential (Bertram *et al.*, 2015; Kriegler *et al.*, 2015; Luderer *et al.*, 2018) and greatly increases the risk of stranded assets when switching to a 2°C-consistent mitigation pathway (Johnson *et al.*, 2015; ; Riahi *et al.*, 2015; Luderer *et al.*, 2016). Attempting to hold the below 2°C limit from the 2030 emission levels implied by the NDCs would require rapid emission reductions after 2030, resulting in stranded assets of several hundred billion US$ from coal power alone (Johnson *et al.*, 2015). Coal-based power is the most important cause of carbon lock-in today (Davis *et al.*, 2010; Bertram *et al.*, 2015; UNEP, 2017), with all plants currently in operation committing the world to around 190 $GtCO_2$ (UNEP, 2017; Edenhofer *et al.*, 2018). If all coal-fired power plants currently under construction go into operation and run until the end of their technical lifetime, the coal emissions commitment will increase by another 150 $GtCO_2$, jeopardizing the achievement of NDC emission reduction targets and the Paris Agreement's long-term warming limits (Edenhofer *et al.*, 2018). Strengthening 2030 efforts beyond the NDCs will not only reduce near-term emissions, but also crucially reduce carbon lock-in, paving the way for the deep emission reductions required in the longer term.

Chapter 4.
Bridging the gap:
Strengthening NDCs and domestic policies

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4.1 Introduction

The previous chapters of this report highlight the urgency of enhancing ambition and strengthening mitigation action without further delay. This chapter explores how countries can reflect increased mitigation ambition through enhanced Nationally Intended Contributions (NDCs) and strengthened domestic policies. Furthermore, it looks into the opportunities for bridging the emissions gap by delivering on enhanced ambition.

This chapter first sets out the rationale and context for enhancing ambition in NDCs, including the legal context of the Paris Agreement, which requires regularly enhanced ambition through five-year cycles, as well as factors that facilitate greater ambition (section 4.2). Next, it describes existing concepts of mitigation ambition in the context of NDCs, as well as options for them to reflect enhanced ambition in their NDCs (section 4.3). Enhanced ambition sends an important signal to stakeholders regarding mitigation commitment both internationally and domestically. As domestic policies are crucial to translating mitigation ambition into action, this chapter subsequently explores the extent to which main policy types, focusing specifically on G20 members, cover key sectors (section 4.4). Finally, it summarizes the main insights into how much global greenhouse gas (GHG) emissions could be reduced through enhanced ambition and action from different perspectives (section 4.5), before highlighting the main conclusions (section 4.6).

4.2 Rationale and context for enhancing Nationally Determined Contributions

To increase climate ambition over time, the Paris Agreement establishes a five-year pledge-and-review cycle. Under this cycle, Parties prepare and communicate successive NDCs every five years. Each successive NDC is to represent a progression beyond the Party's current NDC, reflecting its highest possible ambition (UNFCCC, 2015). The Agreement notes that developed country Parties should continue taking the lead by setting economy-wide absolute emission reduction targets, while developing country Parties should continue enhancing their mitigation efforts, gradually moving towards economy-wide emission reduction or limitation targets in light of their capabilities and different national circumstances. From 2023, a five-yearly[1] 'global stocktake' will assess collective progress towards the Agreement's long-term goals and inform the next round of NDCs.

Prior to this, the Paris Decision invites those Parties with NDCs for 2025 to communicate a new NDC, and those with NDCs for 2030 to communicate or update their NDC, by 2020. This follows the 2018 Talanoa Dialogue to take stock of Parties' collective efforts in relation to progress towards the Agreement's long-term goals and to inform NDC preparation (see also chapter 1). The Decision also invites Parties to undertake mid-century, long-term, low-GHG emission development strategies, which may in turn inform near-term NDCs and policies (UNFCCC, 2016).

A number of factors have changed since Intended Nationally Determined Contributions (INDCs) were communicated in the lead-up to 2015, creating a new context in which Parties may consider communicating or updating their NDCs for 2020. For example, the Paris Agreement has been adopted and ratified, indicating the terms under which international climate policy will proceed, and a growing number of countries have adopted or strengthened their domestic policy frameworks for addressing climate change (Iacobuta *et al.*, 2018). Furthermore, the price of renewable energy and other low-carbon solutions has continued to fall more rapidly than expected (IRENA, 2018), and countries are continuing to decouple economic growth from GHG emissions. The 2018 Global Climate Action Summit revealed new actions and commitments on the part of non-state actors.

1 Unless otherwise decided by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.

Box 4.1 Examples of enhanced mitigation ambition in NDCs

Several Parties have either enhanced the ambition of their NDCs relative to their INDCs or have articulated their intent to do so.[2] For instance, Morocco has moved from a 13 percent to a 17 percent unconditional reduction in GHG emissions relative to a business-as-usual scenario by 2030, while increasing its conditional target from 31 to 41 percent. Argentina and Indonesia have also adopted more modest increases in GHG target stringency. Likewise, Morocco, Nepal, Pakistan, Sri Lanka and Uruguay have adopted new commitments and actions, while Mali has adopted an unconditional GHG target in addition to its existing conditional target (Fransen *et al.*, 2017).

4.3 Options for Parties to enhance mitigation ambition

Chapters 2 and 3 presented detailed estimates of the level of GHG emissions that will occur in future years if a country implements its NDC, and if it continues to implement its current domestic policies. The two seldom match, for multiple reasons. First, countries may need time – often many years – to adopt and begin to implement the domestic policies necessary to achieving the targets contained in their NDCs. In the meantime, NDCs will reflect a higher level of mitigation ambition (that is, lower future emissions) than current domestic policies. In other cases, countries may establish relatively conservative NDCs, and then, through domestic policies or other economic trends, find themselves on track to over-deliver. In these cases, NDCs will reflect a lower level of mitigation ambition (that is, higher future emissions) than will domestic policies. Finally, some Parties intend to purchase offsets to close any gap between their domestic policy ambition and their NDC commitments, in which case current policies would reflect future emissions that were higher than NDC targets, but which would be offset.

Ultimately, as domestic policy has the power to control emissions, through regulation or economic incentives, ambitious NDC goals will be irrelevant unless domestic policy follows suit. Nevertheless, the ambition reflected in NDCs is also important because it signals to the international community the contribution that the country intends to make to solve the global issue of climate change, and it delineates the commitments on which the country will report to the international community. This section therefore outlines options for increasing ambition both in NDCs and in domestic policy.

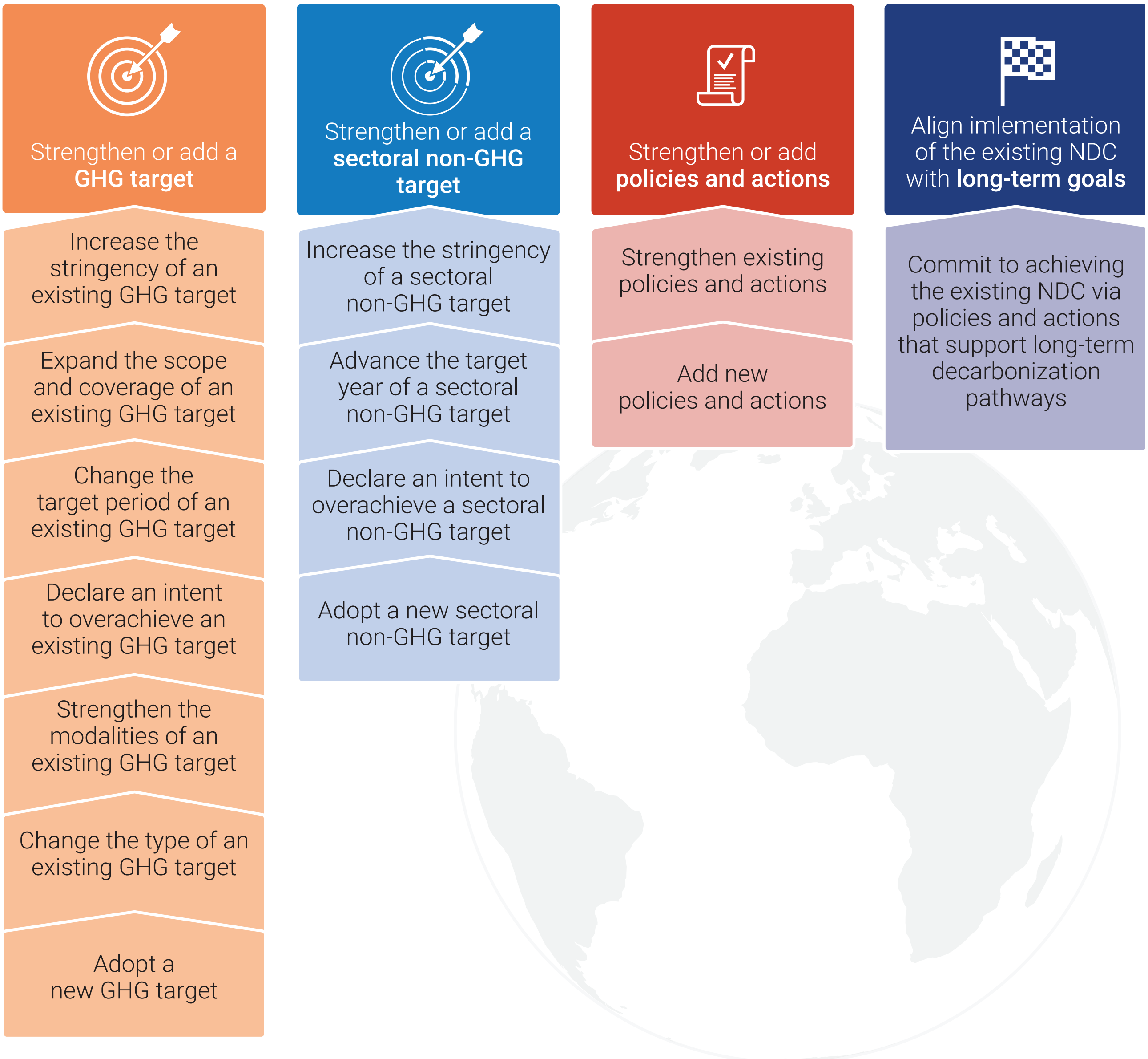
An NDC with enhanced mitigation ambition can be defined as an NDC that "if fully implemented, would result in lower cumulative [GHG] emissions than the fully implemented existing NDC" (Fransen *et al.*, 2017). Furthermore, it is argued that "ambition should be viewed as a combination of target-setting, preparedness to implement, and a capacity to sustain further reductions over time" (Levaï and Baron, 2017). While both definitions consider the impact on cumulative emissions, the latter more explicitly considers a time frame to mid-century, as well as implementation capacity.

There are a number of ways in which a country could reflect enhanced mitigation ambition in its NDC: figure 4.1 illustrates four categories of options for doing so (based on Fransen *et al.* (2017)). First, a country could strengthen its existing GHG target, for example by increasing its stringency, expanding the sectors and gases that it covers or strengthening its modalities, such as those related to land-sector accounting or market mechanisms. It could also adopt a new GHG target. Second, it could pursue similar options *vis-à-vis* sectoral non-GHG targets, such as those to enhance renewable energy or energy efficiency or to limit deforestation. Third, a country could opt to strengthen or expand the policies and actions mentioned in its NDC. At sufficient scale, this could enhance the NDC's overall ambition, as well as providing confidence in the country's preparedness to implement. Finally, the country could commit to an implementation pathway that will sustain GHG reductions over the long term, limiting cumulative emissions.

These options are not mutually exclusive and whether an NDC revision results in enhanced ambition according to the definitions above depends on the scale of the revision, rather than how it is articulated in the NDC. It is important for countries to consider a wide range of options, in order to identify those that are most meaningful and practical in their unique circumstances, and in order to enable deep emission reductions.

2 https://www.wri.org/blog/2018/04/insider-whats-changing-countries-turn-indcs-ndcs-5-early-insights.

Figure 4.1: Typology of strengthening mitigation ambition of NDCs.



Source: adapted from Fransen *et al.* (2017).

4.4 Strengthening domestic policies

Domestic policies are critical for translating mitigation ambition into action. The suite of domestic policies to address climate change can be strengthened, both by expanding policy coverage to additional sectors and issues and by enhancing the stringency of existing policies.

A number of studies and initiatives analyze the coverage and stringency of domestic policies in G20 member countries (see, for example, OECD, 2016; CD-LINKS, 2018; Climate Transparency, 2018). As described in chapter 2, these countries account for roughly 78 percent of global emissions. These studies find that there is significant scope for enhancing the 'coverage' of G20 members' national policies – that is, the presence of a policy addressing a particular sector, without considering its stringency. Evaluation of the coverage of 'good-practice polices' highlights that while policies to support, for example, renewables in the electricity sector are widespread (100 percent of G20 members), coverage is scattered in other areas. To illustrate (CD-LINKS, 2018):

- Reducing transport-related fossil fuel subsidies is covered by only 38 percent of G20 countries.
- Overarching carbon pricing for the electricity sector is covered by only 44 percent of G20 members.
- Material efficiency measures in industry show 38 percent coverage, while CH_4 from oil and gas production have 38 percent coverage.
- Support schemes for using renewables in buildings' heating and cooling systems are covered by only 19 percent of G20 members.
- Emission standards for heavy duty vehicles are covered by 56 percent, while e-mobility programs are covered by 31 percent of G20 members.

Even if an area is covered by a policy instrument or policy package, the stringency of policies varies significantly between countries. Assessments of stringency are more challenging than those of coverage and direct comparison is difficult due to very different domestic circumstances and choices of policy instruments. Although methods to rate the stringency of policy packages are emerging, there are still relatively few. For example, the Allianz Climate & Energy Monitor (Allianz, 2017) compares the stringency of a policy package to support renewables in the electricity sector of G20 countries; the Climate Change Performance Index (CCPI, 2018) rates overall climate performance using expert surveys; and the OECD (2016) assesses and compares the stringency of environmental policies in OECD countries. A common insight from these initiatives is that there is significant potential to enhance the stringency of domestic policies in all countries, including in the area of carbon pricing, which is explored further in chapter 6.

A few examples of policies that have had – or could have – a significant effect on reducing GHG emissions are given below (based on Fekete *et al.*, 2015; Kriegler *et al.*, 2018; Roelfsema *et al.*, 2018). These areas could be used as a starting point for countries to consider options to expand the coverage or stringency of their policies:

- **Renewable electricity** share in global total electricity generation has increased significantly in the EU-28 by, on average, 1.5 percentage points/year during 2005–2014 (IEA, 2016). This increase is related to the Renewable Energy Directive (European Parliament, 2009), which is implemented in member states in various ways.
- **Phase-out of unabated coal-fired power plants** (that is, without Carbon Capture and Storage (CCS)), is planned in a number of EU countries (Jones and Gutmann, 2015). At the subnational level, Alberta (Government of Alberta, no date) and Ontario in Canada phased them out in 2014 (Harris *et al.*, 2015), followed by South Australia in 2016 (Parkinson, 2016). Canada has a plan to phase out coal-fired power plants without CCS by 2030 (Government of Canada, 2016). Meanwhile, India's Electricity Plan (Central Electricity Authority, 2018) also projects significantly fewer new coal-fired power plants than previously planned.
- In terms of **industrial energy efficiency**, there is only limited evidence that existing policies in major emitting countries have made significant impact well beyond business-as-usual. The literature suggests that autonomous energy efficiency improvement is about 1 percent annually (Blok, 2004; UNIDO, 2010) and an improvement of anywhere close to 2 percent annually is considered challenging, especially in developed economies (Blok, 2004).
- In **heating and cooling** for new buildings, a particularly stringent example is the EU Energy Performance of Buildings Directive (European Parliament, 2010), which calls for all new buildings to be nearly zero energy by 2020. The EU also has an encouraging national target to renovate 3 percent of all public buildings/year to increase their efficiency. Nevertheless, challenges remain in implementing these targets.
- For **electrical appliances and lighting**, Japan's Top Runner Program (METI, 2015) is worth mentioning. The energy efficiency improvement rates for 24 appliances (including heating and cooling as well as cooking appliances) over varying time periods of 4-9 years was, on average, 0.9 percentage points/year higher than the targeted rates (Ibid.).
- The global market share for **electric vehicles** (EVs) is still small, with 3 million sales in 2017 (IEA, 2018). In Norway, however, EVs (including plug-in hybrids) accounted for nearly 39 percent of new cars in 2017 (IEA, 2018) and even higher recently. A multi-layered policy package comprised of financial incentives and behavioral incentives (e.g. allowing EV drivers to use bus lanes and free public parking) contributed to these high EV sales (Figenbaum *et al.*, 2015).
- For **fuel economy of new vehicles**, the EU sets one of the strictest standards in the world (Yang and Bandivadekar, 2017), recognizing that there is a performance gap between test mode and real-world fuel-economy figures, estimated at 30 percent (ICCT, 2016).
- For **freight transport**, only Japan, the USA, Canada and China have CO_2 or efficiency standards for heavy duty vehicles (Muncrief and Rodriguez, 2017); the USA and Canada have separate engine standards in addition to full-vehicle regulations, including aerodynamic and rolling resistance to specifically drive improvements in engine efficiency.

Gaps in coverage as well as stringency suggest that there is considerable scope for countries to strengthen their domestic policies and to achieve emission reductions that are considerably beyond the ambition reflected in current policies and NDCs.

4.5 The scope for bridging the emissions gap through enhanced ambition and strengthened action

This section explores the answers to two central questions of the Emissions Gap Reports: Is it possible to bridge the emissions gap by 2030? What are the main opportunities? It summarizes the main insights into how much global GHG emissions could be reduced through enhanced ambition and action from different perspectives: by realizing the full technical potential for mitigation; applying existing good-practice policies universally; maximizing development benefits; and filling gaps in NDC coverage. These perspectives offer different, but not mutually exclusive, lenses through which to approach both domestic policies and NDC enhancement.

4.5.1 Technical mitigation potential in 2030

Estimates of the technical mitigation potential shed light on the upper limit for emission reductions in given future years. The 2017 edition of the Emissions Gap Report (UNEP, 2017) provided an updated assessment of the sectoral emission reduction potentials that are technically and economically feasible in 2030, considering prices up to US$100/t$CO_2$e.[3] The assessment showed that, based on basic potentials, global emissions could be reduced by 33 (range of 30–36) GtCO_2e/year in 2030, compared to the current policy scenario of 59 GtCO_2e/year (chapter 3). If, in addition, a number of newer and less certain mitigation options were included, the mitigation potential would increase to 38 (range of 35–41) GtCO_2e. The emissions reduction potential is thus sufficient to bridge the gap in 2030. It is more than twice the size of the emissions gap for 2°C and still sufficient to bring global emissions in 2030 to a level consistent with least-cost 1.5°C pathways. However, the significantly higher 1.5°C gap estimated in this year's report implies that there would be less leeway in delivering the required emissions reductions.

Estimates of technical emission reduction potential differ significantly between studies and realizing the potentials assumes that all technologies available are fully deployed nationally and globally. The feasibility of this depends on removing various barriers, including technical, financial, capacity and political barriers. However, it is worth noting that around 40 percent of the technical mitigation potential is estimated to comprise measures in solar and wind energy, efficient appliances, efficient passenger cars, afforestation, and avoiding deforestation (UNEP, 2017). All these measures can be realized at low and, in some cases, net-negative incremental costs and primarily build on proven policies. While national circumstances determine the scope and appropriateness of specific measures, studies point to significant mitigation potential in all countries.

4.5.2 Good-practice policies and their global application

Since 2012, the Emissions Gap Reports have provided examples of policies in key areas and sectors that have proven successful in reducing GHG emissions in countries and regions around the world, while contributing to national development goals (an overview of sectors and issues covered in previous Emissions Gap Reports is provided at the end of this report). Such policies have the potential to make a significant contribution to bridging the gap, if they are scaled up in terms of their ambition and geographical coverage.

Several studies provide estimates of the global emission reductions that could be achieved, if existing good-practice policies were replicated universally (see for example Afanador *et al.*, 2015; Fekete *et al.*, 2015; Kriegler *et al.*, 2018; Roelfsema *et al.*, 2018). The studies differ in assumptions, approaches and policies covered, and subsequently also in their estimates of global emission reduction potentials. However, they typically find that global emissions in 2030 could be reduced to levels of between 42–49 GtCO_2e/year. The studies highlight that significant potential exists in all countries and that replication of proven good-practice policies could reduce global emissions considerably compared to the full implementation of the current NDCs, thereby narrowing the 2030 gap compared to a 2°C pathway.

As studies of the global emission reduction potential from universal replication of existing good-practice policies do not consider the implementation of all technically feasible options, they arrive at lower reduction estimates than those based on total technical mitigation potential. On the other hand, their implementation may be more feasible as the policies considered have already been proven in some countries. However, they may not be directly applicable to all other countries.

4.5.3 Maximizing sustainable development benefits

National development priorities such as economic development, reduced air pollution, employment, and energy security are often the main drivers of domestic policies. However, as mentioned above, sound climate change policies will often contribute to national development goals and vice versa.

A growing number of studies analyze how maximization of development benefits can reduce global GHG emissions significantly in the near future, thereby contributing to narrowing the gap. The New Climate Economy report of 2015 (The New Climate Economy, 2015), for example, estimated that actions in eight focus areas could achieve significant economic benefits and reduce global GHG emissions by between 43–53 GtCO_2e in 2030. The New Climate Economy report (2018) states that "low-carbon growth could deliver economic benefits of US$26 trillion to 2030". Other studies find that meeting a trajectory compatible with the Paris Agreement's long-term goals can support the fulfilment of Sustainable Development Goals (SDGs) in terms of energy access, clean water, air pollution and food security (McCollum *et al.*, 2018). The IEA World Energy Outlook (IEA, 2017) includes a sustainable development scenario, which meets the Paris Agreement's long-term goals and achieves cleaner air and universal access to modern energy and reducing energy security risks.

4.5.4 Filling gaps in NDC coverage

One option for enhancing ambition in the NDCs is to expand them to cover all sectors and gases (see figure 4.1). Previous studies have reviewed the emission reduction potential associated with expanding the coverage of current NDCs to all sectors and gases. Assuming that reductions achieved in the newly covered

3 An order of magnitude referred to by, for example, Stiglitz *et al.* (2017).

sectors and gases are comparable with those in sectors and gases currently covered by NDCs, the global potential is limited to a few $GtCO_2e$ by 2030 (Rogelj *et al.*, 2016). At the same time, countries could elect to go beyond the existing level of ambition in increasing their coverage. Ross *et al.* (2018) finds significant potential, including development benefits, in addressing short-lived climate pollutants. However, while some countries have important gaps to fill in sectors and gases, from a global perspective, the bulk of the mitigation potential lies in strengthening the emissions reductions from sectors and gases that are already covered by NDCs.

4.6 Summary

To bridge the 2030 emissions gap and ensure long-term decarbonization consistent with the Paris Agreement goals, countries must enhance their mitigation ambition. This chapter has illustrated how enhanced ambition can be reflected in revised NDCs as well as in domestic policies, each with unique value. NDCs establish international accountability and convey a direction of travel to both domestic and international stakeholders, while domestic policies directly incentivize actions to reduce emissions.

When considering the mitigation ambition of either NDCs or domestic policies, it is important to consider the effect not only on the 2030 emissions gap, but also on long-term emissions trajectories to mid-century.

There are a range of options for enhancing both the coverage and stringency of domestic policies, including of G20 members. While all G20 countries have policies to support renewables in the electricity sector, stringency of these policies can still be enhanced. Gaps in both coverage and stringency remain in, for example, fossil fuel subsidy reduction, material efficiency measures in industry, oil and gas methane, support schemes for renewables in heating and cooling, emission standards for heavy duty vehicles, and e-mobility programmes.

Chapter 6 looks at the role that strengthened fiscal policies can play in creating stronger incentives for low-carbon investments and for reducing GHG emissions, with a particular emphasis on carbon pricing.

The technical potential for reducing GHG emissions is significant and could be sufficient to bridge the emissions gap in 2030. Three broad areas have the largest potential: renewable energy from wind and solar power; energy-efficient appliances and cars; and afforestation and stopping deforestation.

In all countries, there is significant potential to realize a substantive part of the technical mitigation potential by replicating proven good-practice policies that can simultaneously contribute to key Sustainable Development Goals (SDGs). Realizing this potential would narrow the gap by 2030 significantly beyond current NDCs.

This chapter summarizes only an initial list of perspectives, leaving out a number of important perspectives and opportunities. Non-state and subnational actors in particular have the opportunity both to be part of implementing mitigation commitments made at the national level and to go beyond current pledges and create the space for, and the trust of, national governments to raise ambition. Chapter 5 assesses the role of these actors in enhancing global climate ambition and bridging the emissions gap, based on the most recent literature.

Another important issue is the role that accelerated innovation can play in bridging the emissions gap and realizing the longer-term emission reductions required to achieve the goals of the Paris Agreement with global implications. Chapter 7 explores how combining innovation in behavior and in the use of existing technologies with promoting investment in new technologies and market inventions has the potential to radically transform societies and reduce global GHG emissions.

Chapter 5. Bridging the gap: The role of non-state and subnational actors

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5.1 Introduction

Global climate change governance is diversifying rapidly: in recent years, political attention has been acknowledging the increasingly important role of non-state and subnational actors such as cities, states, regions, companies, investors, foundations, civil society organizations, and cooperative initiatives.

This chapter, assesses the role of non-state and subnational actors' in enhancing global climate ambition and bridging the emissions gap, based on the most recent literature.

The chapter begins with a brief overview of the increasing engagement of non-state and subnational actors (NSAs) in the UNFCCC process (section 5.2), before examining the landscape and trends in terms of NSAs' individual commitments and international cooperative initiatives (ICIs) (section 5.3). Section 5.4 provides an assessment of the emission reduction potentials estimated by the latest studies and looks at non-quantifiable, roles of NSAs that have important implications for global climate change governance. The final section summarizes some of the key ways forward for harnessing the potential of NSAs' climate action to bridge the emissions gap (section 5.5).

5.2 Non-state and subnational actors and climate change negotiations: from Paris to Katowice

The 2015 Conference of the Parties to the UNFCCC held in Paris showed an increased institutionalization of NSA processes and engagement (UNEP, 2016), paving the way for NSAs to play an increasingly prominent role in supporting Parties' mitigation and adaptation efforts. Specifically, the Paris Agreement:

- Encourages Parties to work closely with non-Party stakeholders[1] to catalyze efforts to strengthen mitigation and adaptation action (paragraph 118).
- Encourages non-Party stakeholders to register their climate actions in the Non- State Actor Zone for Climate Action platform (paragraph 117).
- Convenes a high-level event building on the Lima–Paris Action Agenda during the period 2016–2020 in conjunction with each session of the Conference of the Parties (paragraph 120).
- Appoints two high-level champions on behalf of the President of the Conference of the Parties to catalyze NSAs (paragraph 121).

Following Paris, the first two high-level champions[2] launched the Marrakech Partnership for Global Climate Action during the 2016 Conference of the Parties to continue mobilizing NSAs' support of the Parties, and alignment with the Sustainable Development Goals (MP Work Programme 2017–2018).

During the 2017 Conference of the Parties, the champions were asked to align the Marrakech Partnership with the 2018 Talanoa Dialogue that takes stock of Parties' efforts towards the Paris Agreement goals and aims to inform the preparation of new or updated NDCs by 2020 (Decision 1/CP.23, Annex II). They also presented the first yearbook on climate action that reports on NSA actions and is expected to inform the Talanoa Dialogue. By April 2018, 109 NSA inputs had been registered with the Talanoa Dialogue, which will take place at the 24th Conference of the Parties in Katowice December 2018.

In parallel with the UNFCCC process, national and regional initiatives have emerged to stimulate and support NSAs in the European Union, Latin America and Asia, among others (Chan *et al.*, 2018).

1 Non-Party Stakeholders is the term the UNFCCC uses for NSAs.

2 Dr. Laurence Tubiana (France) and Dr. Hakima El Haite (Morocco).

In September 2018, the Global Climate Action Summit held in San Francisco, CA showcased climate actions by NSAs around the world, convening over 4,500 local and regional governments and business leaders (Global Climate Action Summit, 2018). More than 500 announcements were made, including:

- A coalition of over 100 subnational leaders and CEOs committed to become carbon neutral by 2050.
- A 40 percent increase in the number of businesses committing to adopt 'Science-based Targets' in line with the Paris Agreement goals.
- The launch of a forest, food and land-focused coalition aiming to deliver 30 percent of climate solutions needed by 2030.
- A new waste initiative involving more than 20 subnational governments committing to zero waste.
- More ambitious NSA commitments, including California's Governor committing to carbon neutrality by 2045 and a coalition of around 65 members committed to full decarbonization in the 'Powering Past Coal Alliance'.

The outcomes of the Summit will inform the UN 2019 Climate Summit, which will be convened by the UN Secretary General to challenge states, regions, cities, companies, investors and citizens to step up action in six key areas: energy transition, climate finance and carbon pricing, industry transition, nature-based solutions, cities and local action, and resilience.

5.3 Overview of cooperative initiatives and individual commitments by non-state and subnational actor

NSA climate action comes in many forms. This section focuses on two categories: individual NSA actions (section 5.3.1) and cooperative actions through international cooperative initiatives (ICIs) (section 5.3.2), both of which are on the rise. By 1 October 2018, just over 19,136 commitments to action had been recorded in the Non-State Actor Zone for Climate Action (NAZCA), the largest online platform showcasing climate efforts by subnational and non-state actors. Almost two-thirds of these commitments are by individual actors, while just over one-third are cooperative initiatives (including ICIs. See also box 5.1).

Box 5.1 Defining international cooperative initiatives

Although there is no single definition of an international cooperative initiative (ICI), a number of terms and common characteristics help characterize them. When non-state or subnational actors from at least two different countries "adhere to rules and practices that seek to steer behaviour towards shared, public goals" across borders (Andonova *et al.*, 2017), they engage in "transnational climate governance" (Andonova *et al.*, 2009). Broader coalitions made up of countries, companies, non-governmental organizations (NGOs), academia, international organizations or subnational public actors, such as cities and regions, form cooperative initiatives (Blok *et al.*, 2012). When these coalitions cross national borders they become "international cooperative initiatives" (Widerberg and Pattberg, 2015).

Box 5.2 Framing climate action in developing countries

Linking sustainable development and climate change provides a powerful rationale for climate action. Evidence suggests that citizens are more likely to take climate action, or to support government action on climate change, if the sustainable development benefits of these efforts are emphasized (Floater *et al.*, 2016). Communicating the sustainable development gains that are often co-generated alongside climate mitigation or adaptation may be particularly important among NSAs in developing countries and the Global South.

One example is the Indian city of Rajkot, which "has emerged as a climate innovator" by focusing on projects that deliver urban development benefits, and support climate action as a supplementary goal or co-benefit. The political feasibility of climate action increases when connected to "more familiar, and often more immediate, urban priorities" (Bhardwaj and Khosla, 2017).

However, if actions and policies that generate substantial mitigation or adaptation benefits are framed and registered according to their ability to reduce poverty, create jobs, foster economic growth, or protect public health, they may fall under the radar of climate accounting efforts. This might be one of the reasons for the lower representation of NSA climate action in developing countries and the Global South.

5.3.1 Individual commitments by non-state and subnational actors

Individual NSA climate actions are referred to as 'commitment', 'action', 'initiative', and 'target' and include a "diverse set of governance activities taking place beyond strictly government and intergovernmental (or multilateral) settings" (Chan and Pauw, 2014).

NSAs often pledge climate action through networks that collate individual climate pledges and inventories (for example, C40 Cities for Climate Leadership) or reporting platforms such as the CDP (formerly known as the Carbon Disclosure Project). The criteria for participation within these networks and platforms vary: some networks require members to pledge specific commitments, such as greenhouse gas (GHG) emission reduction targets, or to submit regular emissions inventories. Others emphasize peer-to-peer knowledge sharing and capacity-building, while some are membership-based networks that do not require actors to commit to specific goals.

While these networks capture many NSA climate actions, they do not comprehensively cover all NSA climate actions occurring globally.

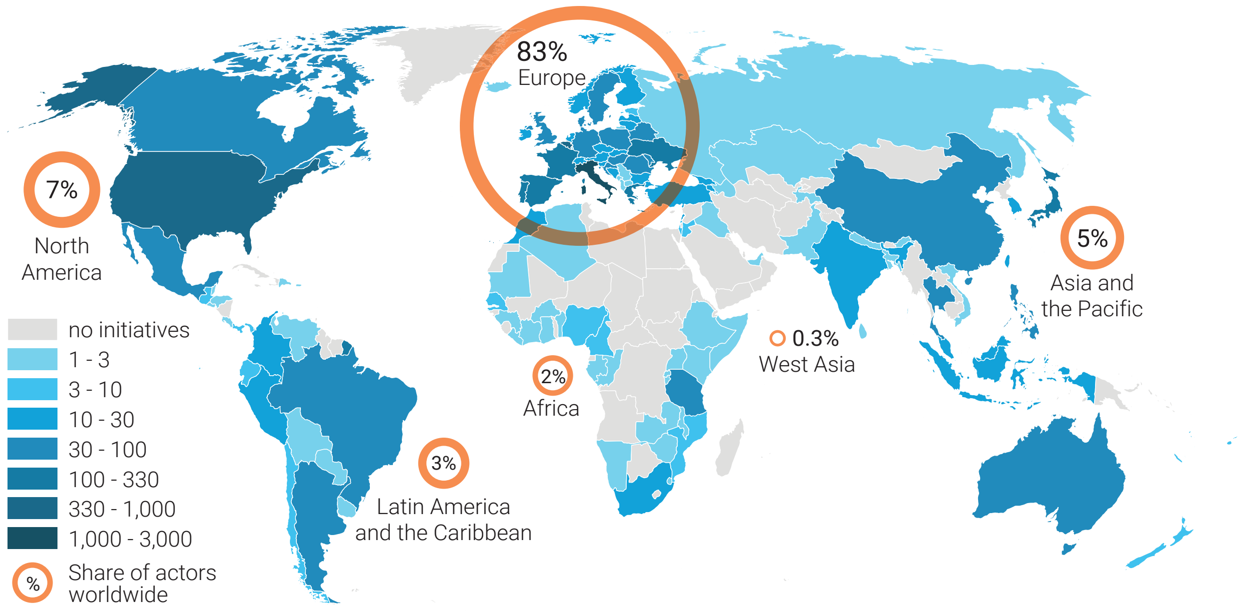
For instance, national networks of NSAs and individual actions that are not reported in global climate action databases are not included in the analysis here (see also box 5.2). Analysis suggests, however, that individual NSA participation through these networks has increased since the 2015 Paris climate negotiations (table 5.1 - possible overlaps are not taken into account). These positive trends indicate the continued and growing role of NSAs in global climate governance. The following section captures an overview of some of these NSA constellations and their membership.

Table 5.1: Examples of the growth in individual NSA actor participation from 2015 to 2017.

Actor group	2015	2017
Cities	7,025 from 99 countries, representing 11 percent of the global population	7,378 from 133 countries, representing 16.9 percent of the global population
States and regions	116 regions from 20 countries, representing 11 percent of the global population	245 regions from 42 countries, representing 17.5 percent of the global population
Companies and investors	4,431 companies from 88 countries and over 400 investors, with more than US$25 trillion in assets under management	6,225 companies and investors from 120 countries, representing at least US$36.5 trillion in revenue
Banks	15 of the 20 largest banks	34 of the 57 largest banks, representing US$3.1 trillion in market capitalization
Higher education institutes	Not assessed	700 colleges and universities in the United States of America, with a total student population nearing 1 million and a collective endowment of over US$250 billion

Data source: Hsu *et al.*, 2015b; Hsu *et al.*, 2016, Hsu *et al.*, 2017.

Figure 5.1: Regional distribution of NSA city participants in carbonn, C40 Cities, CDP Cities, Global Covenant of Mayors for Climate & Energy, and Climate Mayors



Source: Data-Driven Yale, NewClimate Institute and PBL Netherlands (2018).

Subnational governments – cities, states and regions

There are several networks connecting city, state and regional action on climate change. Figure 5.1 illustrates the number of NSA city participants and their geographical distribution in some networks., including the Global Covenant of Mayors for Climate & Energy, signed by 9,149 cities representing 780.8 million people worldwide or just over 10 percent of the global population (Global Covenant of Mayors for Climate & Energy, 2018). The Global Covenant of Mayors for Climate & Energy includes the EU Covenant of Mayors for Climate & Energy that reports 7,755 signatories with 252.6 million inhabitants within the EU (EU Covenant, 2018). All of these members commit to either submitting individual Sustainable Energy and Climate Action Plans or pledging a 40 percent reduction in carbon dioxide emissions by 2030. ICLEI, a global network of subnational governments, has developed the carbonn Climate Registry that includes more than 1,000 cities, towns and regions, drawn from 89 countries and accounting for 9 percent of the world's total population (ICLEI, 2018a).

In terms of state and regional governments taking action, the Compact of States and Regions (2017) includes 110 regional governments from 36 countries, representing 658 million people and 18 percent of the world economy and baseline emissions of 3.9 $GtCO_2e$. These governments have committed to 290 climate actions focused on emissions reductions, renewable energy and energy efficiency that are estimated to result in total (cumulative) emissions reductions of 21.9 $GtCO_2e$ between 2010 and 2050, if climate targets are reached on time (The Climate Group, 2017).

Companies and investors

CDP reports that over 6,300 companies representing a combined purchasing power of over US$3 trillion responded to their climate change questionnaire, and that over 650 investors with assets of US$87 trillion participate (CDP, 2018). In 2017, CDP recorded primary data from over 4,800 companies, of which 47 percent noted an emissions reduction or renewable energy target (CDP, 2018).

A few reports detail financial investors' actions on climate change. The Climate Bonds Initiative's 2018 Green Bonds Summary found that US$74.6 billion in green bonds were issued during the first half of 2018, by 156 issuers from 31 countries (Climate Bonds Initiative, 2018). The United States of America and China topped the list of countries where the most bonds were issued, and most proceeds support projects in the energy, buildings, and land-use sectors (Climate Bonds Initiative, 2018). The Low Carbon Investment Registry currently includes 53 investors from 21 countries, with US$50 billion in low-carbon assets (Global Investor Coalition on Climate Change, 2018) – a slight increase on the 2014 assessment, which found 45 investors reporting investments valued at US$24 billion, most of which (44 percent) focused on renewable energy (Global Investor Coalition on Climate Change, 2014).

5.3.2 International cooperative initiatives

By engaging large and growing numbers of NSAs, international cooperative initiatives (ICIs) can lead to considerable emission reductions, provided that their stated goals are realized and emissions reductions do not displace action elsewhere (Blok *et al.*, 2012; Hsu *et al.*, 2015; UNEP, 2015; Widerberg and Pattberg, 2015; Graichen *et al.*, 2017; see also section 5.4).

In addition to direct emission reductions, ICIs can play a number of other important roles, including providing proofs of concept for low-emissions development strategies, spurring technology development and diffusion, and helping generate momentum for additional initiatives and activities (Weischer *et al.*, 2012).

Several databases collect information on ICIs. They vary in number of initiatives, often due to different definitions of ICIs, purposes, focus areas, data collection methods and sources (UNEP, 2016; Widerberg and Stripple, 2016). The summary of trends in this section focuses on mitigation-related ICIs and is based on data from the Climate Initiatives Platform, which is regularly updated, includes clear criteria for inclusion, and is publicly accessible.[3]

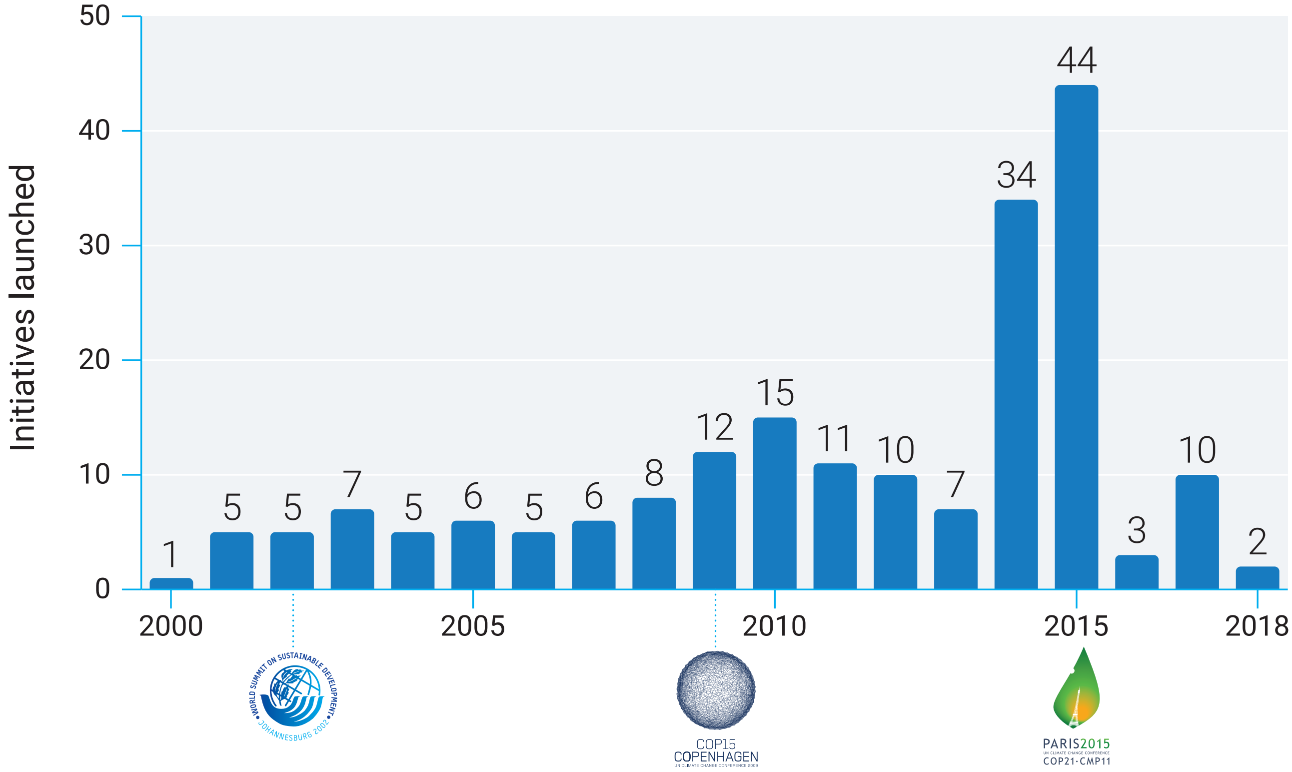
The main features of these ICIs are captured in figures 5.2 and 5.3.

Trend in numbers of ICIs

The Climate Initiatives Platform currently records 244 initiatives, of which 220 are mitigation- focused and are implemented in more than one country.[4] Since the 2016 UN Environment Emissions Gap Report, 17 new initiatives have been added to the platform.

Over the past two decades, the number of ICIs has grown significantly, with peaks in launches of new initiatives

Figure 5.2: Number of international cooperative initiatives launched each year, between 2000 and 2018.



Source: Climate Initiatives Platform [accessed 1 July 2018].

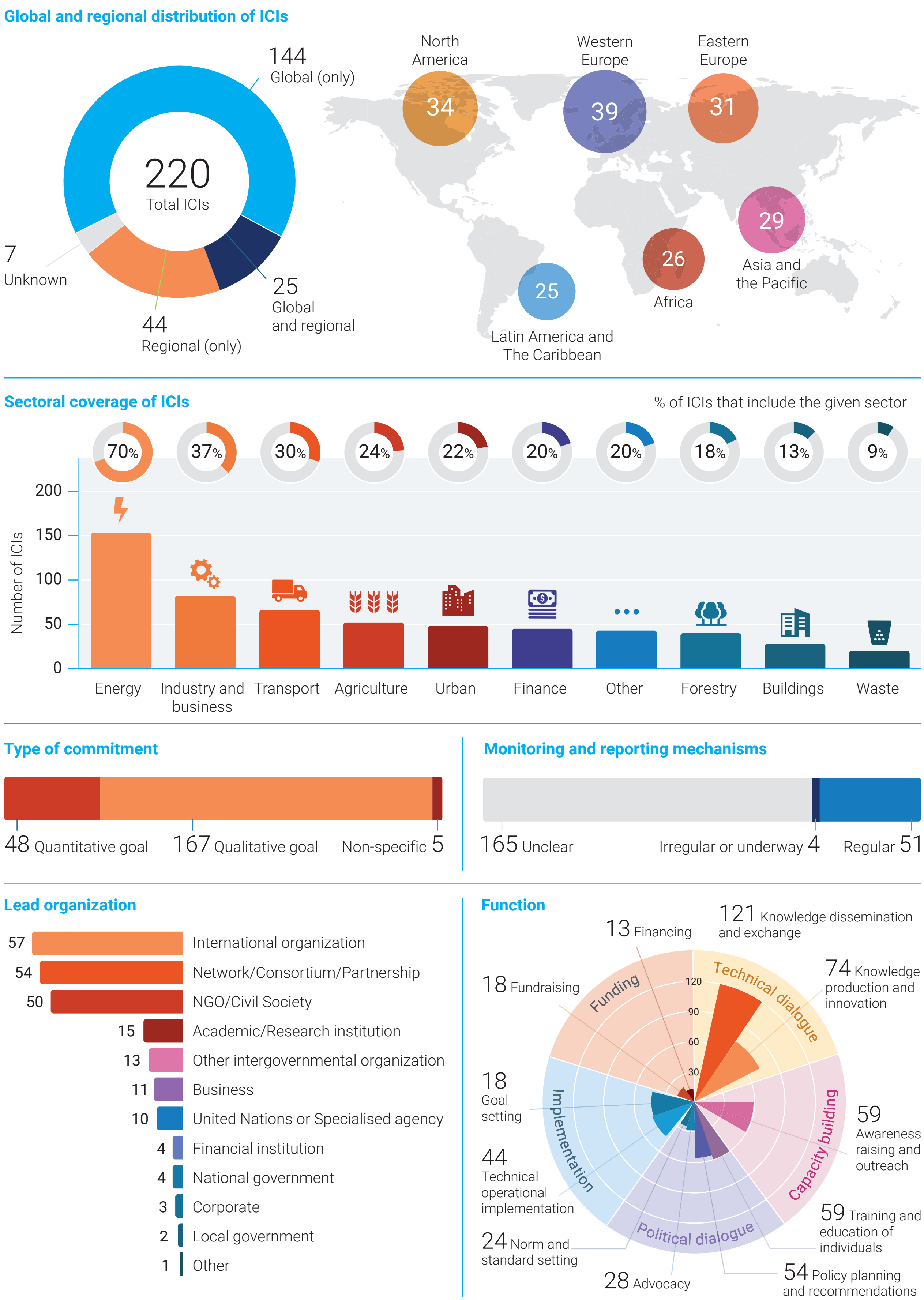
3 **The Climate Initiatives Platform is hosted by UN Environment and the UNEP DTU Partnership.**
It includes ICIs that fulfil the following criteria:

- Includes several non-state actors taking voluntary action, and may also include states.
- Have an objective to reduce GHG emissions or to increase resilience, or could bring about GHG emission reductions or increased resilience.
- Have an international scope or the potential for significant impact on a global scale.
- Have a focal point.

Source: http://climateinitiativesplatform.org/index.php/Climate_Database:About.

4 As at 25 August 2018.

Figure 5.3: Overview of features of 220 mitigation-focused ICIs.



Note: Many initiatives are active in several regions and sectors, and include multiple lead organizations and functions. The numbers and percentages in this figure include all recordings by initiatives, explaining why totals for some elements are higher than 220 initiatives and 100 percent.

around large climate events such as COP 15 in 2009, the United Nations Climate Action Summit convened by United Nations Secretary-General Ban Ki-moon in 2014, and COP 21 in 2015 (figure 5.2). The slowdown in the number of new initiatives in 2016, 2017 and 2018 may reflect a shift in focus towards implementing the initiatives created in earlier years, as well as the importance of global political forums in catalyzing the formation of ICIs.

Regional participation

As figure 5.3 illustrates, many initiatives operate in several regions. Although the overall increase in recorded mitigation-focused ICIs since 2016 is relatively limited, regional participation in ICIs has increased in nearly every region of the world. The biggest increase is in Latin America and the Caribbean, where the number of ICIs has increased from 6 in 2016 to 25 in 2018. In Western Europe, Asia and the Pacific, regional participation has roughly doubled compared with 2016. It is worth noting that global ICIs may be active in regions with relatively low participation in regional ICIs, such as South-Eastern Asia and the Middle East. Furthermore, while ICI activities have been concentrated in high- and middle-income countries (Pattberg *et al.*, 2012; Chan *et al.*, 2015; Chan *et al.*, 2018), the number of ICIs operating in lower-income countries grew dramatically between 2015 and 2017, rising by 56 percent in low-income countries, and 50 percent in lower-middle income countries (United Nations Climate Change Secretariat, 2017).[5] Despite this progress, a sizeable North-South gap remains, with only 22 percent of ICI participation and 23 percent of lead partners from non-OECD countries (ClimateSouth, 2018).

Sectors

Most ICIs (149 out of 220) cover multiple sectors, generally focusing on key sectors where the mitigation potential is significantly higher than the emission reductions implied by current policies and NDCs: the energy, industry, forestry, transport, agriculture, and building sectors (UNEP, 2017). An ICI's sectoral emphasis often shifts according to the needs and capacities of the regions where it is implemented. Actions focused on resilience and agriculture, for example, are most commonly implemented in low-income and middle-income economies, while initiatives addressing the industrial sector are most prevalent in high-income or upper-middle income economies (Chan *et al.*, 2018).

Setting goals and tracking progress

The percentage of ICIs that have set quantitative goals remains low, at around 22 percent. Quantitative goals – defined as a specific, measurable goal made either by an initiative or an initiative's members – range from focusing on emissions reduction (for example, reduce emissions by a specific amount by a specific year), to fund-raising (for example, raise, distribute or invest a specific amount of funds), to capacity-building (for example, reach a specific number of people or communities). Similar low levels of quantitative goals are reported in other studies (Pattberg *et al.*, 2012; Hsu *et al.*, 2015; Widerberg and Stripple, 2016; Graichen *et al.*, 2017; Michaelowa and Michaelowa, 2017; Chan *et al.*, 2018).

Graichen *et al.* (2017) found that 75 percent of the 174 ICIs they surveyed either did not include sufficient information about their targets, had unclear goals, or did not propose concrete actions. Focusing on emissions reduction targets, Hsu *et al.* (2015) found that just 8 out of 29 initiatives contained explicit emissions mitigation targets tied to a particular year. A study conducted by UNEP (2015) used a similar approach to narrow a list of 184 initiatives down to 15. However, among initiatives with clear emissions reductions targets, many have made more ambitious emission reduction commitments than national governments (Graichen *et al.*, 2017).

Monitoring, reporting, and verification practices also remain weak across ICIs: just under 23 percent of ICIs on the Climate Initiatives Platform noted regular monitoring or reporting mechanisms. Other studies also report relatively low percentages of initiatives with established monitoring and reporting mechanisms, ranging from 31 percent (Graichen *et al.* 2017), to 43 percent (Pattberg *et al.*, 2012) or 44 percent (Chan *et al.* 2018). Hsu *et al.* (2015a) found that more than half (18) of 29 ICIs announced at the United Nations Climate Action Summit convened by United Nations Secretary-General Ban Ki- moon in 2014 included provisions for monitoring progress, but that very few of these identified specific indicators to track performance. Bansard *et al.* (2016) likewise noted that the type and stringency of monitoring requirements varied widely among city-focused initiatives. Furthermore, many initiatives do not conduct or share cost estimates or feasibility studies, adding an additional barrier to efforts to assess the feasibility and identify potential barriers to initiatives (Roelfsema *et al.*, 2015). Striving for "more and better" data collection (Widerberg and Stripple, 2016) from initiatives is required to facilitate efforts to assess ICIs' progress and anticipate their contributions to climate action and sustainable development efforts (Roelfsema *et al.*, 2015; Widerberg and Pattberg, 2015; Hsu *et al.*, 2016). Some ICIs have developed approaches that demonstrate how this could be accomplished. The Bonn Challenge, for instance, maintains an interactive online dashboard tracking its signatories' commitments, and their potential collective progress towards the initiative's goal.[6]

5 Part of the increase may include adaptation-focused ICIs.

6 See http://www.bonnchallenge.org/.

Lead organization and secretariat

The existence of a secretariat and a lead organization is likely to influence ICI performance (Pattberg and Widerberg, 2016). Initiatives with a permanent secretariat report both higher-than-average potential emission reduction contributions in 2020 and 2030, and higher indirect impacts, complementary goals and co-benefits, such as diffusion of information, political effects, technology development, reduced air pollution, improved health, and strengthened energy security and economic development (Graichen *et al.*, 2017). Similarly, the active involvement of NGOs, as either leaders or ICI members, has been shown to be associated with higher potential emission reductions and potentially larger co-benefits (Graichen *et al.*, 2017).

Almost all (217) of the ICIs included in CIP state that they have a secretariat, in many cases hosted by one of the larger organizations participating in the ICI, but it is not possible to assess how many of these secretariats are permanent. In fact, some studies suggest that most ICIs lack a permanent secretariat (Graichen *et al.*, 2017; Chan, 2018).

Functions

ICIs primarily provide information and knowledge-related services to their participants (figure 5.3). Although the distribution of functions has remained relatively stable over time, a few new functions have recently emerged, including financing and fund-raising. In a recent survey of 75 ICIs, funding was found to be the most common challenge, reported by approximately 30 percent of respondents (UNFCCC, 2017). Meanwhile, financial and organizational capacity tends to be associated with high-performing ICIs (Biermann *et al.*, 2007; Chan and Pauw, 2014; Chan *et al.*, 2015; Galvanizing the Groundswell of Climate Actions, 2015; Widerberg and Pattberg 2015). The recent growth in ICIs' fund-raising and financing activities is therefore promising and may suggest increased efforts to address the challenges reported.

5.4 The potential contribution of non-state and subnational actors to enhancing ambition and bridging the 2030 emissions gap

At the international level, there is particular interest in how much NSAs could contribute to global GHG emission reductions by 2030 and the extent to which these potential contributions are already included in national current policy and NDC estimates. Section 5.4.1 assesses the most recent studies on these issues, while section 5.4.2 addresses the questions related to tracking the progress and results of NSA action. NSAs also play a number of critical roles that do not easily lend themselves to quantification, but may nevertheless be important to enhancing ambition and bridging the 2030 emissions gap. Section 5.4.3 provides a brief overview of such roles.

5.4.1 Estimates of potential emission reductions in 2030 of non-state and subnational actors

The 2016 Emissions Gap Report (UNEP 2016) published an overview of quantitative analysis of the potential contribution of NSA actions to global emissions mitigation in 2030, illustrating a wide range of results. Since these estimates were published, the number of studies that quantify NSAs' potential contribution to global climate action has grown, with more networks and researchers conducting analysis of aggregate impact of member groups on global emissions. These studies can be divided into three categories:

1. **Individual commitments:** estimate the aggregate impact on emissions from pledges by individual cities, regions or business actors that commit to fully implement the targets they set themselves.
2. **Single initiatives:** estimate the potential impact on emissions from a single cooperative initiative goal, assuming this is implemented by all actors under the initiative. Often, individual actors subscribe to a collective cooperative initiative (which can be an ICI) that together sets a goal for the initiative. The single initiative studies assess the emission reductions of the initiative's goals, rather than pledges that individual actors take themselves. The estimated emission reductions subsequently involve some scaling up of the potential.
3. **Scaled-up potential of multiple initiatives:** estimate the potential emission reductions from several initiatives that would occur if the initiatives reached a transformative impact at the sector- or economy-wide level. These studies apply a range of significant assumptions on how actions are expanded; from assuming that all members within a network will adopt an ICI's ambitious emission reduction goal, to that membership will grow to a certain number of actors and cover a certain number of additional sectors. These studies therefore estimate greater reduction potential at the sector- or economy-wide level.

Table 5.2 provides an overview of available studies, organized according to these three categories. The table shows the wide range of potential emission reductions estimated in various studies – from companies based in the United States of America contributing 0.026 $GtCO_2e$ in 2025 (America's Pledge 2018) to as much as 15-23 $GtCO_2e$ in 2030 based on an evaluation of the scaled-up potential of 21 cross-sector, multi- actor ICIs (Data-Driven Yale, NewClimate Institute and PBL, 2018).

Due to the variable baseline methodologies and assumptions adopted by each study, as well as different scopes in terms of actors and emissions covered, the wide range of overall impact assessment is unsurprising. Some studies focus on NSA impact in a single country, such as the United States of America (Roelfsema, 2017),

Table 5.2: Potential greenhouse gas emission reductions of selected individual commitments and initiatives (in $MtCO_2e$/year in 2025/2030, by study).

Actors and sectors	1) Individual commitments					2) Single initiatives					3) Scaled-up potential of multiple initiatives				
	CDP (2016)	ICLEI (2015)	Kuramochi *et al.* (2017)	Roelfsema (2017)	Data-Driven Yale, New Climate Institute, and PBL (2018)	America's Pledge (2018)	Arup and C40 Cities for Climate Leadership Network (2014)	The Climate Group and CDP, Compact of States and Regions (2017)	Compact of Mayors (2015)	Global Covenant of Mayors (2018)	CDP and We Mean Business (2016)	Roelfsema *et al.* (2018)	Graichen *et al.*, (2017)	Erickson and Tempest (2014)	Data-Driven Yale, New Climate Institute, and PBL (2018)
Cities and municipalities		179 by 2035	360–560 by 2025	3–30	1,550–2,200 (current policy scenario 1a); 200–700 (NDC scenario 1b)	500 in 2025	402		740	1,400				3,700	
Regions								550							
Business	1,000					.026 in 2025					3,200–4,200				
ICIs												5,500	5,000–11,000		15,000–23,000
Number of actors or initiatives quantified	1,089 companies	116 cities	54 cities, 22 regions, 250 companies	25 cities	2,175 companies, 76 regions, 5,910 cities	155 businesses, 115 cities, 20 states	228 cities	110 regional governments	360 cities	9,149 cities	5 ICIs including ~ 300 companies	11 ICIs	19 ICIs	600+ cities	21 ICIs
Baseline scenario of the study	Not specified - variable according to individual company actor	Not specified - variable according to individual city actor	Current national policies scenario	Current national policies + NDCs	Current policy scenario and NDCs scenario	Business as usual	Business as usual (no policy baseline)	Compared to 'reference technology scenario' that includes current policies and the NDCs	Business as usual (no policy baseline)	Business as usual (no policy baseline)	Current national policies scenario	Counter-factual (no policy baseline)	Current national policies scenario plus NDCs	Current policy scenario	Current policy scenario and NDCs Scenario
Overlaps quantified?			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓

Note: This table only evaluates reports that include estimated impact in 2025/2030 and excludes those with pre-2025 or post-2030 assessment timeframes. Source: Adapted from Hsu *et al.* (forthcoming).

while other single initiative studies evaluate emissions savings relative to business-as-usual scenarios for the actor group, rather than comparing to a global scenario. Only some studies report a range of results that take into consideration assumptions such as a lower and upper range of results (We Mean Business, 2016; Graichen *et al.* 2017; Kuramochi *et al.*, 2017; Roelfsema, 2017 and Data-Driven Yale, NewClimate Institute and PBL, 2018), and even fewer conduct sensitivity analysis.

Some reports, such as the U.S. Climate Alliance (2017) report analyzing 15 regions' contributions to GHG reductions or the Nordic Council of Ministers' report (Nordic Council of Ministers 2017), do not provide an aggregate quantified assessment of impact. They are therefore not included in table 5.2.

Studies included in table 5.2 all assume various baseline scenarios against which they assess additional impact of NSAs. These baseline scenarios range from study-specific "business as usual" or no-action scenarios, to "current policy scenarios" that take into account a range of existing government policies and pledges, to an "NDC scenario" that assumes that countries implement their NDCs under the Paris Agreement (table 5.2; Hsu *et al.*, forthcoming). Consequently, it is challenging to compare the estimated impact across studies, although meta-analysis of methodologies applied in each study demonstrate similar approaches, including the use of the Greenhouse Gas Protocol standard for distinguishing between direct and indirect emissions (Hsu *et al.*, forthcoming). Specifications of baseline scenarios by which to compare additional NSA contributions are also increasingly converging to common terminology and methods.

A major question with respect to NSA climate mitigation contribution is the extent to which they lead to emission reductions that are not accounted for in current national policies or in the NDCs. A limited number of the available studies assess NSA mitigation impact relative to global current policy and NDCs based on an assessment of overlap scenarios (see table 5.2). These quantitative assessments of overlap determine the ambition level of NSA commitments *vis-à-vis* current policy scenarios and NDC scenarios by comparing the rate of emissions decline in actors' targets (Kuramochi *et al.*, 2017). For instance, if a city's emission reduction target results in a steeper rate of decline in overall emissions compared to a national government's NDC, a common assumption is to consider the emissions reductions that are beyond what a national actor has pledged as "additional" reductions.

One analysis focused on the United States of America (Kuramochi *et al.*, 2017), found that 17 states and 54 cities with recorded GHG mitigation commitments comprising 40 percent of national U.S. emissions were found to have the potential to meet almost half of the country's NDC by 2025. Another study that quantified nearly 6,000 subnational and over 2,000 business commitments determined that emissions would be 0.2-0.7 $GtCO_2e$/year lower in 2030 than with NDCs alone (Data-DrivenYale, NewClimate Institute, and PBL, 2018, Figure 5.4).

Figures 5.4a and 5.4b illustrates the wide range of potential emission reductions estimated in various studies. The figure includes the studies from table 5.2 that have clear and comparable baseline scenario definitions by which to assess the magnitude of additional impact. An assessment of each of the studies' baseline estimates was made to ensure their comparable to the Emissions Gap Report scenario values for 2030. Figure 5.4a includes estimates from studies that aggregate from a bottom-up method of *pledged 2030 commitments* made by individual actors. As this figure illustrates, the pledged 2030 contribution by NSAs, if fully realized, is estimated to lead to limited additional emission reductions (ranging from 3-700 $MtCO_2e$, as indicated in Table 5.2) compared to the full implementation of the unconditional NDCs.

Figure 5.4b includes estimates of *scaled-up potential emission reductions* based on an assessment of single initiative goals and multiple initiatives' goals. These studies assume that all actors participating within their initiative fully implement and achieve the larger goal of an initiative and therefore represent "scaled-up" potential that is larger than the estimates in figure 5.4a. The studies behind the estimates in figure 5.4b apply a range of assumptions on how actions are expanded, from assuming that all members within a network will adopt an ICI's ambitious emission reduction goal, to that membership will grow to a certain number of actors and cover a certain number of additional sectors.

The figure indicates that NSAs have the potential to contribute significantly to bridging the 2030 emissions gap, but that realizing this potential requires commitments and action that go far beyond current recorded and quantified individual actor pledges as well as single initiatives.

5.4.2 Tracking progress and results of non-state and subnational actors

Data limitations and gaps

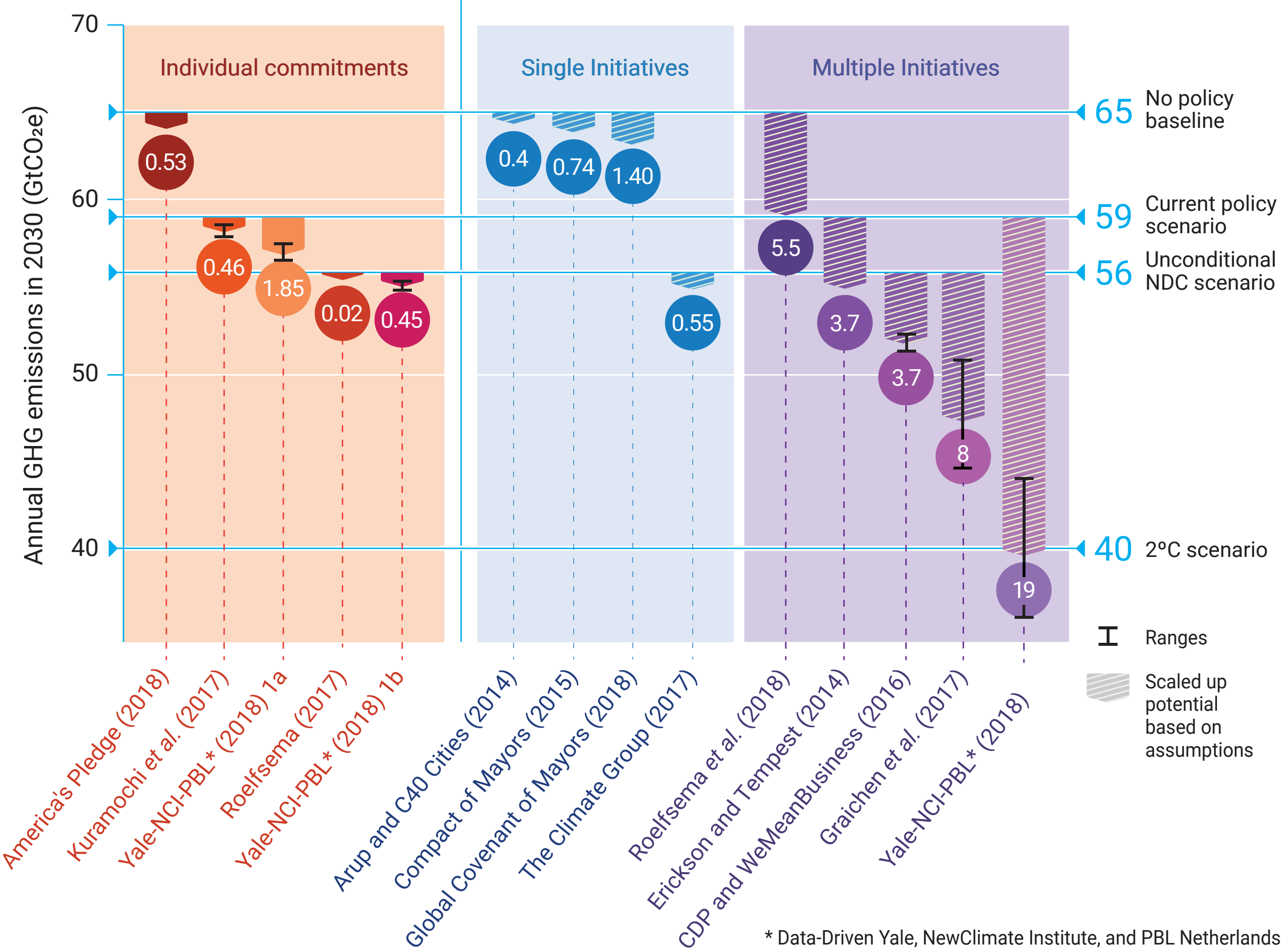
As the previous sections illustrate, limited availability, consistency and comparability of data pose significant challenges to evaluating the potential NSA impact on climate mitigation and their other benefits. For instance, Bansard *et al.* (2016) found in their evaluation of cities participating in the C40 Cities for Climate Leadership Network that out of around 40 members evaluated, nine different base years with seven different target years were found, making an evaluation and comparison of targets and level of ambition difficult.

Although Non-State Actor Zone for Climate Action (NAZCA) acts as an umbrella for various NSA climate action repositories, no comprehensive database of NSA actions exists, with each NSA adopting various criteria for inclusion that are often unclear or opaque (Widerberg and Stripple, 2016). The reported data are often not suited to calculating emissions impact, estimating overlap, or comparing NSA mitigation potential to the emissions scenarios of other actors, such as national governments.

Figure 5.4: The range of estimated potential emission reductions in various NSA studies.

Figure 5.4a: Emission reduction potential of pledged commitments by NSAs.

Figure 5.4b: Scaled up potential emission reductions based on single and multiple initiatives.



Source: Based on data in table 5.2.

Note: a) For studies that include ranges, median estimates are provided with ranges indicated in Figures 5.4a and 5.4b.
b) Studies that are cross-hatched evaluate single and multiple ICI goals rather than individual actors' recorded and quantified pledges. They rely on assumptions of future scaled-up impact and therefore represent potential rather than a quantified analysis of individual actors' NSA pledges.
c) Extrapolation of 2025 estimates has been made.

Key information, such as actors' target and baseline emissions, emissions scopes (that is, direct or indirect), and inventory emissions with historic time-series available, are often inconsistently reported (if at all), with subnational actors from the European Union reporting the largest amount of data required for mitigation impact assessments and the greatest gaps found in emerging and developing countries (Hsu *et al.*, 2018, forthcoming).

Finally, as the estimates and numbers in this report exclude national cooperative initiatives and networks, they underestimate the scale and spread of NSA climate actions, particularly in regions where actors have less access or capability to engage with transnational initiatives.

Some efforts under way to address data reporting and methodological consistency should help improve the future data landscape for analyzing NSAs' contributions. For example, the World Resources Institute's Greenhouse Gas Protocol Initiative released in 2015 (the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (Fong *et al.*, 2015)) and a consortium of non-government institutes, through the Initiative for Climate Action Transparency (ICAT), are currently developing guidance for NSAs, national governments and other audiences to account for and measure NSA climate mitigation contributions (see also box 5.3). These and other efforts should help improve consistency among NSA-reported data.

Box 5.3 Monitoring, reporting and verification success stories

Monitoring, reporting and verifying the emissions inventories and commitments of both national actors and NSAs is key to global climate change assessment and governance, as there is a risk that actors participate in transnational climate governance initiatives to "greenwash" or boost their reputations, without setting or implementing meaningful climate action targets (Okereke, 2007; Mayer and Gereffi, 2010; Hsu *et al.*, 2016). Some NSAs, however, are making their emissions inventories more transparent and making progress on implementing climate actions. For example, Scotland, Wales, and the Australian Capital Territory all compile particularly comprehensive GHG emissions inventories, which account for the emissions of one or more GHGs from sources within a defined space and time. Each government also goes one step further, by having these inventories externally verified.

Note: This box draws on insights shared by The Climate Group's Compact of States and Regions initiative.[7]

Box 5.4 Improving monitoring, reporting and verification in international cooperative initiatives

Many initiatives are improving their commitment pledging and evaluation process. For example, CDP is starting to collect this information through its Assessing Low-Carbon Transition (ACT) initiative that provides data, indicators and feedback for companies to align their targets with 2°C scenarios. An application of ACT is the Corporate Climate Action Benchmark (CCAB) developed by CDP and the World Benchmarking Alliance (WBA). From 2019 onwards, the CCAB measures the climate action performance of high emitting companies on a yearly basis, allowing stakeholders to monitor progress. The aim of the CCAB is threefold: incentivize companies to align their strategies and operations with a well below 2°C pathway, create a race to the top by rewarding companies that are best in class, and visualize progress of corporate climate action between 2020 and 2030. Some city networks, including ICLEI and the EU Covenant of Mayors, are reporting on their members' progress, although currently only a fraction (1,743 out of more than 6,000 members with action plans) list progress reports on their website. The Science-Based Targets initiative helps companies to set internal climate targets that are aligned with the long-term mitigation goals of the Paris Agreement. The initiative currently includes over 100 companies with science-based targets and over 300 companies wanting to develop such targets.

Tracking progress on NSA implementation achievement of targets

Although efforts to improve the monitoring, reporting and evaluation of NSA actions are increasing (see previous section and box 5.4), studies and information regarding NSA implementation – progress towards achieving targets and whether actors are meeting their goals – are still scarce (Chan *et al.*, 2018; 2015). Part of the difficulty of tracking implementation is that ex-post measurement of results is largely lacking, given the nascent nature of many NSA climate actions. Therefore, most available studies quantifying the mitigation impact of NSAs assess their potential emission reductions, rather than ex-post or achieved results. An exception is ICLEI's (2018b) report analyzing the drivers of emissions reductions based on 138 local governments submitting inventories and reporting on policy efforts.

To bolster confidence in NSA contributions to bridging the 2030 emissions gap, data on implementation are critical to understanding whether current targets and goals are being reached and 2030 potentials are likely to be achieved.

Some studies question the extent to which NSA implementation and achievements to date have delivered real emission reductions (Chan *et al.*, 2015; 2018; Michaelowa and Michaelowa, 2017). One analysis found that out of more than 300 collaborative non-state partnerships announced at the 2002 World Sustainable Development Summit, nearly 65 percent were yet to be operationalized 10 years later (Pattberg *et al.*, 2012).

Nevertheless, from the studies available, a number of aspects that are likely to influence the implementation and performance of NSA actions are emerging (see also section 5.3.2). Graichen *et al.*, (2017); ICAT, (2018); Michaelowa and Michaelowa, (2017); Pattberg and Widerberg, (2016) show that these aspects include:

7 In particular, we thank Milimer Morgado and Jean-Charles Seghers for their help in compiling these examples.

- Leadership and permanent secretariat (for cooperative initiatives).
- Target clarity and ownership.
- The presence of monitoring and progress reporting mechanisms.
- Past achievement of results, actors' technical capacity.
- Financial incentives and the availability of funding.
- A commitment's vulnerability to political considerations.
- The presence of regulatory support.

It should be noted that while monitoring, reporting and verification procedures are important in terms of enabling learning and boosting credibility among individual actors and initiatives, they may dissuade new NSAs from taking climate action. In ICIs in particular, if the goals and monitoring, reporting and verification procedures are considered too much of an administrative burden, it could discourage their further expansion.

5.4.3 Contributions by non-state and subnational actors beyond direct emission reductions

NSAs' contributions to climate change action go beyond their quantifiable potential emission reductions: they can play a key role in building government confidence in implementing climate policies and they can signal and push for greater ambition. Quantitative analysis that emphasize NSAs' direct contributions to climate mitigation may overlook the critical other roles that they play in global climate change governance, such as capacity-building, knowledge transfer and coalition building, as these important NSA actions are difficult to quantify. Other examples include facilitative or catalytic actions, such as low or zero-carbon norm creation, or policy foundations, such as voluntary emissions registries, which may produce longer-term societal transitions towards decarbonization (van der Ven *et al.*, 2017).

Nevertheless, studies that analyze difficult to quantify NSA roles and functions in national and global climate change governance are emerging. These studies highlight three roles and functions as particularly important:

- Facilitating *catalytic linkages* (for example, Betsill *et al.*, 2015) with national actors that are often informal in nature, but allow for actors such as national governments to address underlying drivers of emissions, build capacity, or shape low-carbon development contexts.
- Acting as potential *orchestrators* (for example, Abbott *et al.*, 2012; Chan *et al.*, 2018) in climate policy implementation and coordination with national and intergovernmental actors.
- Providing *experimentation* (for example, Hoffmann 2011; Bernstein and Hoffmann, 2018) for policy instruments or implementation deemed too risky or costly at the national level.

Box 5.5 provides examples of the orchestration role of NSAs.

Box 5.5 Orchestration of non-state and subnational action around the world

Actors and networks in developed and developing countries are incentivizing NSAs to act, identifying and addressing possible barriers to them doing so, and supporting NSA capacity- building to tackle climate change.

ActionLAC
ActionLAC, a partnership set up by the Latin American Fundación Avina, aims to accelerate climate action and strengthen ambition in Latin America. Targeting actors such as community-based organizations, small enterprises, and local governments, this partnership fosters inclusive climate governance in Latin America. ActionLAC provides support throughout the "life-cycle of climate actions", including elaborating, financing, implementing, evaluating and communicating climate action plans.

Cities and Regions Talanoa Dialogues
ICLEI – Local Governments for Sustainability, together with the Global Covenant of Mayors for Climate & Energy and UN-Habitat, are facilitating Cities and Regions Talanoa Dialogues around the world, in response to similar dialogues in the context of the UNFCCC. These dialogues – 50 of which have been scheduled throughout 2018 – engage actors that have often not been adequately involved in national climate efforts to date, and to advance the New Urban Agenda adopted in 2016. For instance, they explore pathways for actively engaging subnational governments in formulating national climate investment plans. So far, about half of the scheduled dialogues are in developing countries.

European Dialogue on Non-State Climate Action
The European Economic and Social Committee (EESC), the EU advisory body comprising representatives from workers' and employers' organizations, established the European Dialogue on Non-State Climate Action (ED-NSCA). This dialogue aims to strengthen and increase the scope and scale of European-based non-state climate action among constituencies that are often not traditionally known as main actors in environment and climate change, including workers' and employers' organizations in the industrial, agricultural and transport sectors. The European Dialogue envisages supporting non-state climate action by assessing, recognizing, improving, accelerating and supporting actions.

5.5 Opportunities for harnessing the potential of NSA climate action to enhance ambition and bridge the emissions gap

The previous sections illustrate the magnitude, diversity and potential contributions of NSAs to climate change action, forming the basis for a number of recommendations on how to further strengthen NSAs' action to realize their emission reduction potential. These recommendations are briefly summarized below.

First, more actors must engage in climate action. Scaling up individual and collaborative climate action to more geographic areas, sectors and types of actors could significantly contribute to realizing the large mitigation potential of NSAs. NSAs from previously under-represented regions of the world are starting to take action. Many regions, particularly in the Global South, are still under-represented in terms of participants, lead organizations, and the location of secretariats. Encouraging NSAs in developing countries to engage in initiatives would facilitate climate action in growing economies with potentially large and low-cost mitigation potentials. Scaling up also entails ensuring a broad range of sectors, including currently under- represented ones such as oil and gas.

Second, national governments can play a vital role by stimulating this growing movement, and can for example support non-state actors by providing collaboration platforms, capacity building and technical and financial resources. Furthermore, national political institutions are crucial to transnational climate action (Andonova *et al.*, 2017). Governments can also support the implementation of individual commitments. In order to support urban climate action, for example, governments could develop policies and approaches for enhancing the capacity of local governments, including providing financial investments and enabling private investments to lower GHGs (Broekhoff *et al.*, 2018).

Third, transparency is critical to assessing NSA actions and tracking their implementation. This report clearly shows that although progress is being made, transparency and related monitoring, reporting and verification standards require improvement at all levels: individual, cooperative initiative, and global. Commitments are often vague in terms of goals, language and enforcement mechanisms, while different baselines, timelines and assessment frameworks are used to report on progress. Implementing monitoring, reporting and verification mechanisms for cooperative initiatives is particularly important, in order to document tangible results, NSA climate actions could gain credibility among the broader public and decision makers. These mechanisms would also facilitate learning, allowing the organization to assess performance on an ongoing basis and to experiment with new approaches.

Data collection and reporting efforts are starting to enable more sophisticated analysis on the potential for NSA climate action to contribute additional GHG reductions beyond national governments commitments. However, data gaps (particularly in high-emitting sectors and developing countries) limit these analysis, meaning they do not necessarily capture the diversity of the NSA climate action taking place. Particularly where sustainable economic development is a pressing concern, NSA climate action takes on different forms besides participation in transnational climate action networks, focusing also on adaptation, capacity- building and resilience functions that are more difficult to quantify and aggregate on a global scale.

Finally, NSAs play different important roles and functions and their contribution to global climate change governance goes beyond what can be measured in terms of direct emission reductions. These aspects – including orchestration, catalytic effects, and experimentation – should therefore be kept in mind.

Chapter 6. Bridging the gap: Fiscal reforms for the low-carbon transition

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6.1 Introduction

Fiscal policies can affect fossil fuel prices and therefore influence carbon emissions and investments in the energy sector. However, current price signals from excise taxes and carbon pricing are too low and inconsistent to encourage strong and cost-effective mitigation. In some countries, and for some fuels, carbon prices are even negative due to high financial support for fossil fuels. This chapter assesses the fiscal policy gap between current fiscal policy and its potential for reducing carbon emissions and collecting public revenue. It provides country examples and further considerations of how to overcome this gap.

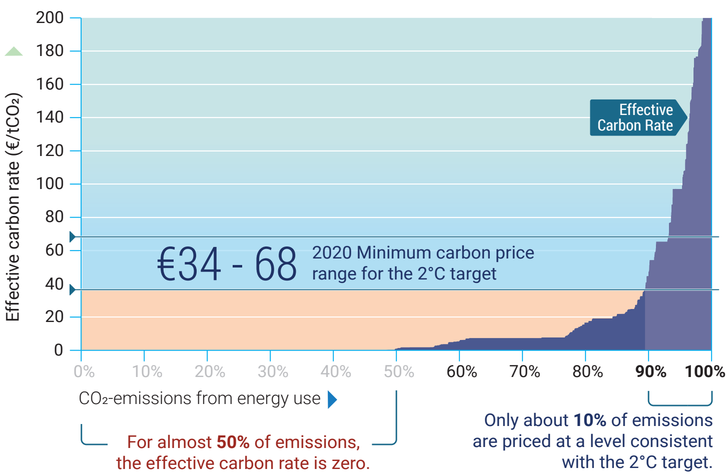
6.2 The current state of fiscal policies and their potential for the low-carbon transition

6.2.1 Carbon pricing

Increasing the price of carbon emissions through carbon taxes or emissions trading systems (ETS) is a core element of climate policy. Before 2005, hardly any emissions were covered by carbon taxes or trading systems (World Bank and Ecofys, 2018). Coverage increased to about 5 percent of global greenhouse gas (GHG) emissions between 2005 and 2010, primarily because of the introduction of the European Union's ETS. Between 2010 and 2018, coverage has risen to about 15 percent of global emissions, with 51 carbon pricing initiatives now installed or scheduled. If China implements carbon pricing as announced, coverage would rise to about 20 percent of global GHG emissions.

While coverage, price levels, and coordination and cooperation efforts are increasing, carbon prices are often low and inconsistent, as illustrated in figure 6.1. This depicts the distribution of carbon rates for energy use across all sectors and fuels for 42 Organization for Economic Cooperation and Development (OECD) and G20 countries, which together represent 80 percent of global CO_2 emissions from energy use (OECD, 2018b). Effective carbon rates are policy-induced increases in (relative) fossil fuel prices, expressed per tonne of CO_2. They include carbon taxes and permit prices related to existing ETS, as well as excise taxes on energy.

Figure 6.1: Effective carbon rates on energy use across 42 OECD and G20 countries (estimate for 2018) and the minimum carbon price range needed in 2020 for the 2°C target.



Note: This figure shows the distribution of effective carbon rates over energy-related CO_2 emissions for 42 OECD and G20 countries, representing 80 percent of global CO_2 emissions. Carbon rates include carbon taxes, permit prices related to existing ETS and excise taxes on energy (also including those not motivated by a climate policy objective). **Source:** OECD, 2018b and own illustration.

1 Opinions expressed are those of the authors and not of the institutions that they are affiliated with. We would like to thank Assia Elgouacem (OECD), Ottmar Edenhofer (MCC), Michael Jakob (MCC) and Ian Parry (IMF) for their input and comments. We would also like to thank Sarah Beyer and Zeljana Ana Grulovic for their assistance.

Excise taxes are by far the largest component of the overall carbon price, although ETS constitute a large share in the electricity sector in most jurisdictions where such systems are in place. Accordingly, revenues from carbon taxes and ETS (US$33 billion [€28 billion][2] in 2017)[3] remain much smaller than those of excise taxes on energy use (ca €421 billion in OECD and G20 countries – Marten and Van Dender, forthcoming). However, excise sales taxes on energy use are often poorly aligned with the carbon content of the tax base. Coal – the most carbon-intensive energy source, and one that also causes significant local environmental damage – is untaxed in most large economies and therefore priced at production cost (Coady *et al.*, 2018). Effective carbon rates tend to be higher for oil products than for other fuels, and they are significantly higher in road transport than in all other sectors.[4] Fuel prices in the European countries with the highest fuel taxes may be high enough to cover non-climate externalities in road transport, including local air pollution, congestion, noise, casualties, and road wear and tear (Santos, 2017; Coady *et al.*, 2018; OECD, 2018a), but they remain too low elsewhere.

Current carbon prices fall short of the levels needed for meeting the targets of the Paris Agreement. The High-Level Commission on Carbon Prices (2017) concludes that the explicit carbon price level consistent with the 2°C target is at least US$40–80/t$CO_2$ [€34–68/tCO_2] by 2020 and US$50–100/t$CO_2$ [€43–86/tCO_2] by 2030. Hence, the lower end of this range indicates the minimum price level needed to close the emissions gap in order to reach the 2°C target. Figure 6.1 shows that approximately 90 percent of the CO_2 emissions from energy use are priced at rates below the lower end: half of the emissions are not priced at all, and an additional 40 percent of emissions are priced at rates below the minimum price level of €34/tCO_2.

Major efforts are needed to increase carbon prices. However, in recent years, progress has been slow, as can be seen from the 'carbon pricing gap' indicator (OECD, 2016 and 2018b). The carbon pricing gap measures the positive differences between a €30 carbon rate and applicable rates across all energy use, as a percentage, and therefore considers the extent of emissions priced below €30. Against this rate, the gap is estimated to be 77 percent in 2018, which is approximately 6 percentage points lower than in 2012 and 3 percentage points lower than in 2015. The rate of reduction needs to be much faster to ensure that carbon rates align with the Paris Agreement targets. The significant carbon pricing gap and the slow progress is partly related to political economy issues, i.e. the distribution of climate policy costs and political and behavioural barriers to fiscal reforms. Section 6.3 will discuss the major obstacles and how to address and overcome these.

6.2.2 Fossil fuel subsidies

Budgetary support for fossil fuels usually reduces prices and can create negative carbon prices. This leads to higher fuel use, GHG emissions and local air pollution. Support includes the direct transfer of funds, market price support (e.g. setting prices that are different from market rates), tax concessions (e.g. exemptions or reductions), in-kind support (e.g. building a railway from a coal mine to a port), credit support (e.g. favourable loans or loan guarantees), below-market insurance rates and caps on liability or preferential government procurement (Steenblik, 2008). Consumer subsidies are mostly used in developing and resource-rich countries. Producer subsidies are found in both developed and developing countries (Bast *et al.*, 2015).

Estimates of fossil fuel subsidy levels differ due to varying coverage and methodologies. In an effort to provide a consistent figure, the International Energy Agency and OECD estimate that subsidies for oil, natural gas and coal amounted to US$373 billion [€319 billion] in 2015, which is 0.5 percent of global gross domestic product (GDP) (OECD, 2018c). Total consumer subsidies declined by 15 percent in 2016 and are currently given to petroleum products (40 percent), electricity (41 percent), natural gas (19 percent) and coal (less than 1 percent) (IEA, 2017). The recent decrease in support is the result of reform efforts and declining global fuel prices. However, this downward trend does not apply to all countries and energy sources; subsidies are increasing for electricity consumption in particular, and in countries including Angola, Azerbaijan, China, Kazakhstan, Malaysia, Mexico and South Africa (IEA, 2017). Rising crude oil prices could drive up subsidies and reverse some reforms.

Reforming fossil fuel subsidies can yield significant public savings. In the Middle East and North Africa (MENA) region, fossil fuel subsidies averaged almost 20 percent of total government spending in the 2013/2014 financial year (El-Katiri and Fattouh, 2017). Similarly, before recent reforms, the share of Indonesia's government expenditure dedicated to fossil fuel subsidies hovered just below 30 percent, and subsequently dropped to 6 percent (NCE, 2018). Fossil fuel consumer price support disproportionally benefits richer households—the top income quintile on average receives six times more in subsidies than the bottom quintile (Coady *et al.*, 2015). Reducing fossil fuel subsidies therefore leads to more equitable distributional outcomes. Moreover, reducing fossil fuel use by reducing fuel subsidies can improve air quality, public health and economic efficiency.

6.2.3 Emissions reduction potential

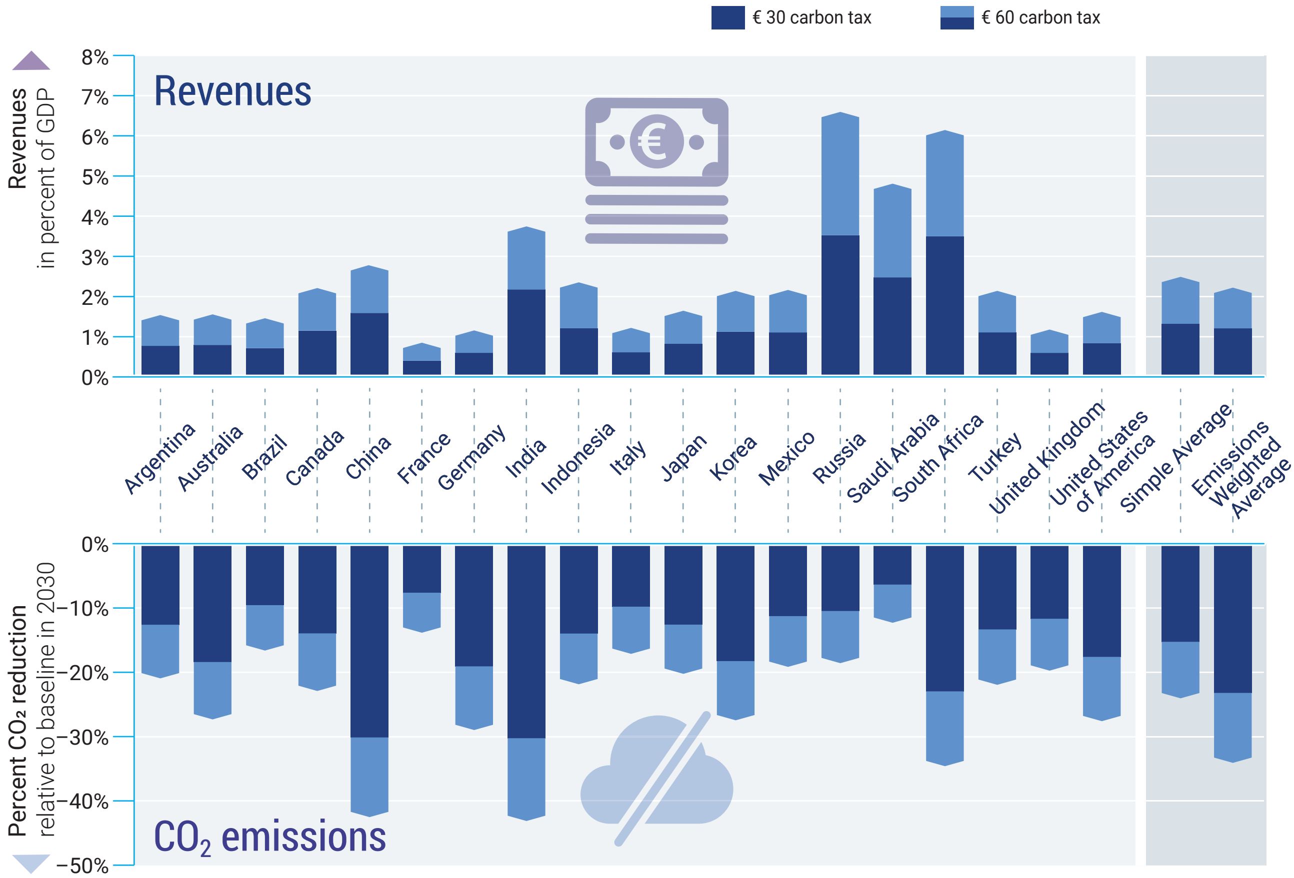
Better alignment of energy taxes across the carbon content of fuels and increases in carbon prices would, over time, reduce demand for fossil fuels. Strong commitment to announced price paths allows investors to make low-carbon investments with sufficient confidence. For example, the Canadian province of British Columbia implemented a schedule to increase carbon taxes by C$5 [€3] per t$CO_2$ per year as of April 2018, increasing from C$35 to C$50 [€24 to €34] per

2 For converting currencies into euros, in this chapter we use the average exchange rate between 2014 and 2017 provided by the Federal Reserve Bank of St. Louis.

3 The revenue is lower than the value of the carbon pricing systems (ca US$82 billion [€70 billion]) because substantial shares of tradable permits are allocated for free.

4 The right tail of the distribution curve in figure 6.1 consists almost entirely of road transport rates.

Figure 6.2: CO_2 reductions (relative to baseline) and revenues (relative to gross domestic product (GDP)) generated from additional carbon taxes of €30/tCO_2 and €60/tCO_2, 2030.



Source: Parry *et al.* (2018).
Note: Calculations assume that carbon prices are implemented in addition to existing measures. Revenue calculations account for induced changes in revenues from pre-existing excise taxes, but not from the broader fiscal system (i.e. income taxes). The original paper refers to carbon taxes of US$35/t$CO_2$ [€30/tCO_2] and US$70/t$CO_2$ [€60/tCO_2]. For comparability with section 6.2, these prices were converted to Euros.

tCO_2 by 2021. Other countries have also substantially increased carbon taxes over time: the carbon tax in France amounts to €44.60 per tCO_2 and is set to rise considerably; Sweden has increased rates to €120 per tCO_2 in 2018 and is also abolishing non-European Union ETS industry exemptions this year; and Switzerland has increased rates to CHF96 [€85] per tCO_2 in 2018). Future price increases could also be rule-based, with carbon prices increasing more significantly if emissions turn out to be higher compared with a benchmark (Murray *et al.*, 2017; Hafstead *et al.*, 2017). Energy taxes can also help reflect other external costs, including air pollution and, to some extent, traffic congestion.

Based on International Monetary Fund estimates (Parry *et al.*, 2018), an additional carbon price of €30/tCO_2 by 2030 could lead to emission reductions of more than 10 percent in many countries. According to the High-Level Commission on Carbon Prices (2017), a carbon price of €60/tCO_2 by 2030 is at the lower end of the spectrum in terms of prices needed to close the emissions gap in order to meet the 2°C target. A price of €60/tCO_2 is estimated to cut emissions by just over 10 percent to more than 40 percent, depending on the country (figure 6.2).

As the presence of fossil fuel subsidies can undermine carbon pricing efforts, subsidy reform is an important complement to carbon pricing. Phasing out fossil fuel support could reduce global emissions by between 1 percent and 11 percent by 2020–2030, although regional emissions reductions, e.g. for the Middle East and North Africa, may be substantially larger (Burniaux and Chateau, 2014; IEA, 2015; Merrill *et al.*, 2015; Gerasimchuk *et al.*, 2017; Jewell *et al.*, 2018). Emission reductions are strongest for oil and natural gas use. Since financial support for coal use is relatively low, subsidy removal has only a small impact on coal consumption, which would be more strongly affected by carbon pricing.

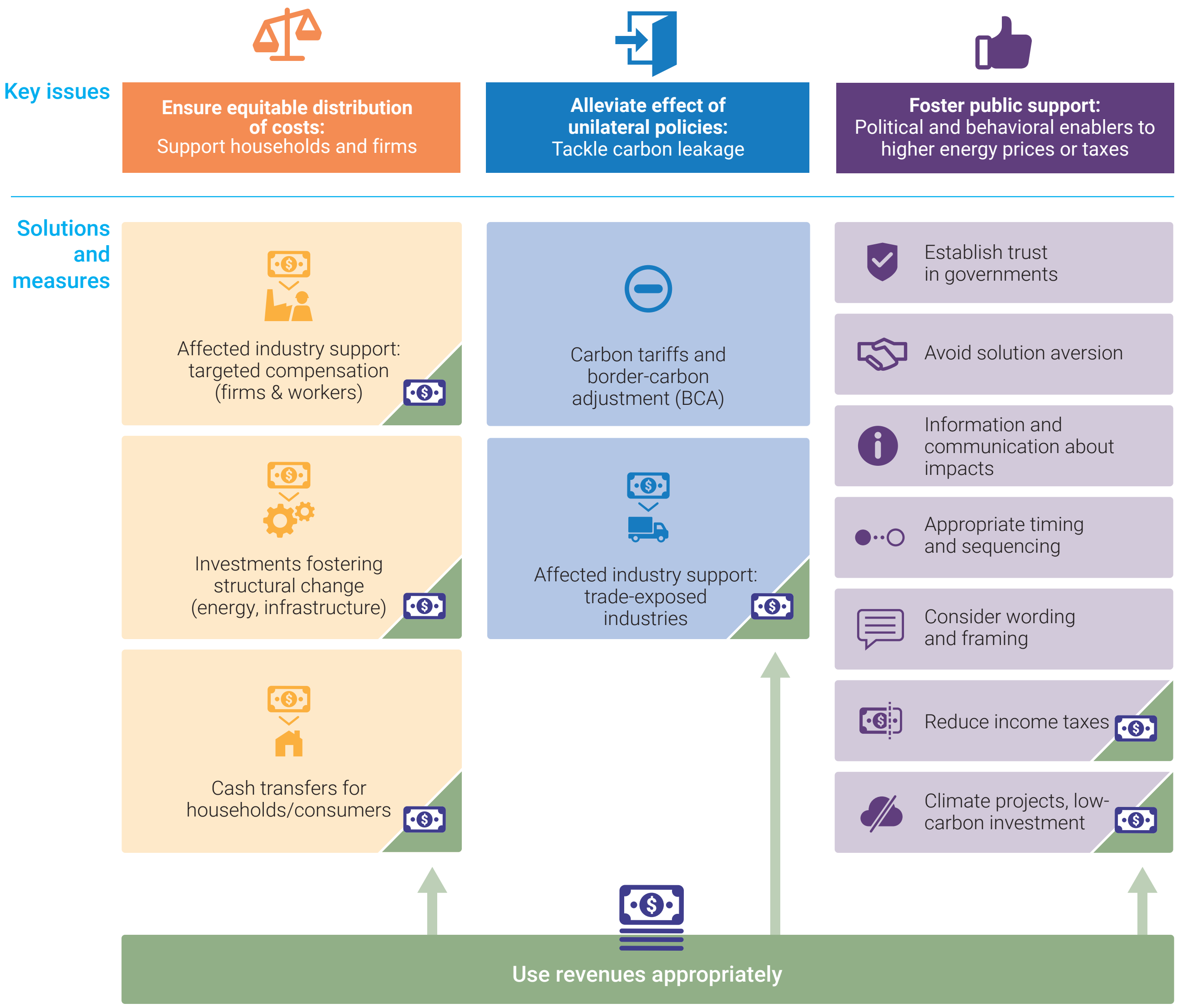
6.3 The political economy of green fiscal reform and carbon taxes: lessons learned

Public support for carbon pricing or the phasing-out of fossil fuel subsidies is often limited, in part because politicians have failed to communicate a clear narrative on how and why this would benefit consumers and the local economy. Key concerns relate to (i) the distribution of costs between households and firms, (ii) limited environmental effectiveness due to leakage of emissions to other jurisdictions and (iii) broader behavioural and political factors. Concerns about reduced competitiveness and relocation of economic activity due to domestic policy can be separated into costs for firms, employment effects and emission leakage, and are therefore covered by (i) and (ii). Figure 6.3 gives an overview of the key issues and proposed measures to address them. As fiscal policies create revenue, they can provide additional space for compensation or other forms of spending to help make carbon pricing more appealing.

6.3.1 Distribution of costs

Carbon taxes and energy subsidies affect prices of production factors, goods and services, so the costs of fiscal policy affect many firms and households (Fullerton, 2011). Addressing the economic costs borne by politically powerful groups can encourage support for reform. Equally, compensating vulnerable and highly disadvantaged groups is important for social inclusiveness and fairness (i.e. reducing poverty and inequality). Higher energy and carbon taxes have a particularly negative effect on:

Figure 6.3: Key issues for making fiscal reforms politically viable (upper part) and solutions and measures to address them (lower part). Measures related to financial flows are marked with a green mark in the bottom corner. Table 6.1 gives country examples of the political and behavioural factors (listed in the third column) while table 6.2 shows different ways to use revenues (green arrows).



1. Owners of carbon-intensive businesses (fossil fuel firms, the steel and cement industries) that have excess or idle production capacity, leading to lower-than-expected returns.
2. Workers in energy-intensive industries who might lose jobs or face lower wages.
3. Owners of fossil resources in situ, who may not be able to extract and sell their products due to lower demand or lower market prices.
4. Households and consumers who spend a relatively high share of their income on energy-intensive goods and services.

The cost for firms often plays a prominent role in public debate about carbon pricing, prompted by their concerns over maintaining global competitiveness, since unilateral policy puts additional costs on domestic business, potentially affecting profits and employment (the impact on relocation of emissions, i.e. leakage, is discussed below). However, the cost to capital owners and workers is only transitory as investment and employment adjust in the long run, without substantial costs resulting from depreciation (capital) and retirement (employment). While costs for firms have been found, on average, to be rather low (Dechezleprêtre and Sato, 2017), they can be high in carbon-intensive firms that would be particularly affected by phasing out fossil fuel subsidies or by higher carbon prices (Jenkins, 2014; Aldy and Pizer, 2015; OECD, 2015, Rentschler *et al.*, 2017). If firms face strong international competition, their ability to pass on higher energy costs to consumers is limited, and this increases their compliance costs.

A common compensation approach is to grant support that is both targeted and time-limited, e.g. exemptions or transfers (Aldy and Pizer, 2015). Allocating permits based on past emissions (known as 'grandfathering') in trading systems, as occurs in the European Union ETS, can mitigate economic losses and prevent industry relocation. However, it also undermines policy effectiveness (Flues and Van Dender, 2017a) and can result in substantial overcompensation for a given carbon leakage risk, as Martin *et al.* (2014) show for the European Union ETS. Reduced corporate income or capital taxes as part of broader fiscal reforms can reduce or even offset the carbon pricing burden on firms (Carbone *et al.*, 2013; Goulder and Hafstead, 2013; Williams III *et al.*, 2014; Rausch and Reilly, 2015). Providing additional training and transitional benefits for workers of affected industries is a more cost-effective way of compensating them than providing direct support to employers, in the longer term (Frondel *et al.*, 2007).

Losses for fossil fuel resource owners due to long-term carbon pricing represent a permanent wealth loss and can be substantial. Ambitious mitigation policies consistent with the 2°C target are estimated to reduce discounted fossil resource rents by roughly 40 percent, compared with a no climate policy scenario (Bauer *et al.*, 2016). However, state revenues from carbon pricing would likely outweigh the losses for fossil resource owners (Kalkuhl and Brecha, 2013; Bauer *et al.*, 2016).

Higher energy prices can affect lower-income or rural households disproportionally (Flues and Thomas, 2015; Levinson and O'Brien, 2018) and may increase energy-poverty risk (Flues and Van Dender, 2017b; Atansah *et al.*, 2017). Carbon pricing tends to be progressive in developing countries, while it is more likely to be regressive in middle- and high-income countries as relatively low-income households have higher expenditure shares on energy-intensive goods and services (Dorband *et al.*, 2018; Ohlendorf *et al.*, 2018). However, middle and high-income countries often have the institutional capacities to overcome these adverse effects by pursuing compensation policies. Transfers on an equal per capita basis are highly beneficial for poor households (Klenert and Mattauch, 2016), but targeted transfers leave more revenue for other purposes. Targeted investment in low-income neighbourhoods (e.g. in public transport, access to clean energy or income tax reductions for poorer households) can mitigate adverse equity effects (Chiroleu-Assouline and Fodha, 2014; Edenhofer *et al.*, 2017; OECD, 2017; Klenert *et al.*, 2018b). Table 6.1 lists examples of measures that have been successfully implemented to protect the poorest households.

6.3.2 Carbon leakage under unilateral policies

A country that unilaterally increases the price of carbon could see emission-intensive production relocate to other countries, which would undermine the effectiveness of carbon pricing (World Bank, 2015). This is known as carbon leakage, which can be fixed by trade and non-trade measures (Jakob *et al.*, 2014). These trade measures include tariffs or charges imposed on countries that do not have comparable carbon prices ('carbon tariffs'). Trade policies can be used strategically to incentivize trade partners to adopt domestic climate policy measures or to increase or maintain a coalition of countries with ambitious climate policies (Barrett, 1997; Lessmann *et al.*, 2009; Nordhaus, 2015). Non-trade policies to reduce the risk of carbon leakage include the grandfathering of emission permits and output-based rebates to energy-intensive and trade-exposed firms.

Border carbon adjustments are a specific form of carbon tariff that involve levying taxes on imported goods according to their carbon footprint and removing the carbon price component of exported goods. Border carbon adjustments aim to level the playing field between domestic and foreign firms by imposing the same economic burden on emissions (Mehling *et al.*, 2018). Introducing border carbon adjustments to carbon prices on domestic emissions is a consumption-based method for pricing emissions. However, implementing border carbon adjustments requires substantial (and accurate) information on production-side emissions and on the direct or implicit carbon prices in exporting countries. Improved monitoring, reporting and verification systems can therefore help make border carbon adjustments more accurate. Moreover, the impact of border carbon adjustments on reducing leakage can be weakened through induced changes in trade and production patterns (Jakob and Marschinski, 2013).

Focusing on particularly carbon-intensive goods (e.g. cement and steel) and conducting an ex ante evaluation on trade impacts can help overcome these downsides and make border carbon adjustments more effective in reducing carbon leakage.

Carbon tariffs are not necessarily compatible with World Trade Organization rules, although they could be covered by Article XX of the General Agreement on Tariffs and Trade (GATT), which stipulates that trade policies can be used for achieving environmental goals if no other policies are feasible that are less distortive to trade (Cosbey *et al.*, 2012). Even so, retaliation can pose an economic risk if carbon tariffs are implemented by countries with a small share on the international market (Hagen and Schneider, 2017; Böhringer and Rutherford, 2017).

6.3.3 Political and behavioural factors

Ensuring broad and stable support for carbon pricing and the phasing-out of fossil fuel subsidies requires more than addressing distributional, competitiveness and leakage impacts. A number of additional success factors can be identified (Klenert *et al.*, 2018a) and table 6.1 provides country examples for addressing these. The challenge is particularly significant where trust in government is limited (Klenert *et al.*, 2018a; Rafaty, 2018). And yet, where trust is strong, there is a tendency for citizens to question problems if policy solutions challenge their world views, e.g. on the State's role in the economy ("solution aversion") (Campbell and Kay, 2014; Cherry *et al.*, 2017). Designing policies that are consistent with the prevailing world views of specific societal groups therefore requires extensive communication and consultation prior to implementation.

To secure popular support for carbon pricing, the public needs to be informed about its positive effect on emissions reduction targets, as well as the co-benefits of cleaner air, health and fiscal sustainability (Hsu *et al.*, 2008; Bristow *et al.*, 2010; Kallbekken *et al.*, 2011; Baranzini *et al.*, 2014; Baranzini and Carattini, 2017). Timing is also important: a gradual reform is more likely to be successful than sudden and drastic price increases. Similarly, if several fossil fuel subsidies are being reformed, this can best be done by sequencing the reforms (Beaton *et al.*, 2013; Rentschler and Bazilian, 2017b). Language matters too, with terms such as 'fee' or 'contribution' likely to meet with popular support compared with 'tax' (Kallbekken *et al.*, 2011; Drews and van den Bergh, 2016; Baranzini and Carattini, 2017).

Carbon pricing and fossil fuel subsidy reform generate public revenues, the use of which can strongly impact support for carbon pricing. This is discussed in the section 6.3.4.

6.3.4 Use revenues from carbon pricing to foster sustainable development

Raising revenue through energy tax reforms relaxes constraints on broader fiscal policy, creating opportunities to stimulate more productive and socially inclusive economic development. With respect to carbon pricing, its potential for contributing to public budgets is illustrated in figure 6.2b. In developing and emerging economies, where tax revenue-to-gross domestic product (GDP) ratios rarely exceed 20 percent, an additional €60/tCO_2 carbon price on top of existing measures would generate revenues worth more than 2 percent of gross domestic product (GDP). These revenues would not be available under non-fiscal climate policies like emission standards or ETS that do not auction permits.

The way these new revenues are used has an effect on the economy and equity, and therefore relates directly to the economic and political arguments for tax-based environment policy. Revenues can be deployed in various ways. Policy packages that combine carbon pricing with political or legal commitments to particular forms of spending have been found to increase the political appeal of, and public support for, fiscal reforms. However, because revenues from environmental taxes might be insufficient or too high for a specific spending objective, legal earmarking of these revenue sources for particular spending items increases the risk of inefficient tax and spending patterns. Maintaining some flexibility for adjusting spending decisions, e.g. through political commitment to policy packages, is therefore important. Options for such policy packages include:

1. Cutting personal or corporate income taxes.
2. Cash transfers.
3. Investment projects aimed at poor or disadvantaged regions or neighbourhoods, or regions traditionally dependent on fossil resource extraction (e.g. coal).
4. Temporarily assisting energy-intensive industries facing strong international competition.
5. Supporting low-carbon technologies or spending that increases environmental quality.

Table 6.2 gives an overview of spending options, including some country-specific examples. Choosing a particular option should be guided by the economic circumstances and political and social priorities of the respective jurisdiction. Some countries, such as Chile, Mexico and Viet Nam, have not earmarked environmental tax revenues or committed to simultaneous tax cuts. Sweden used a soft earmarking approach, reflecting a political commitment to reduce other taxes, in particular labour taxes. The revenue from ETS is more often allocated to green spending than that of carbon taxes and excise taxes and discussions on carbon taxes and excise taxes are more often embedded in broader tax policy reform efforts.

Table 6.1: Behavioural and political success factors.

Success factor	Example(s)
Directly addressing distributional impacts	• LPG price increases in **Brazil** and **Mexico** were combined with existing social welfare mechanisms to mitigate the effects of higher prices (Adeoti *et al.*, 2016; Toft *et al.*, 2016). • Kerosene subsidy reforms in **Indonesia** and **Yemen** were accompanied by measures promoting the use of liquefied petroleum gas (LPG) as a household cooking fuel (Clements *et al.*, 2013). • In **Indonesia**, social assistance programmes enabled the government to reform fossil fuel subsidies in the mid-2000s (Chelminski, 2018), while India and Iran provided some form of cash transfer to compensate households (Rentschler and Bazilian, 2017a; Jain *et al.*, 2018). • **Switzerland**, **Alberta** and **British Columbia** (see table 6.2) have used revenues from carbon pricing to compensate households and, to a degree, firms.
Establishing trust in governments	• Countries with relatively high levels of trust and low levels of perceived corruption, such as **Finland**, **Norway**, **Sweden** and **Switzerland**, tend to have higher carbon prices (Rafaty, 2018). • Subsidy reform in **Indonesia** had previously been difficult due to public distrust in the government; however, more recently, reforms have been accompanied by measures tackling corruption in the oil and gas sector (Chelminski, 2018). • **Jordan's** 2008 subsidy reforms were introduced following consultations with a wide array of stakeholders (Whitley and van der Burg, 2015).
Avoiding solution aversion	• Proposed carbon pricing reforms for the **USA** as a whole, or for individual USA states, are often designed to accommodate less interventionist world views. This is accomplished by minimizing the State's role in the carbon pricing reform, in part by returning a large portion of the revenue to its citizens (Nature Editorial, 2017). Further examples are the **Massachusetts** Bill H.1726—which also features a carbon dividend—that passed the state senate in June 2018 (DeMarco, 2018) or the reform of the **Californian** Cap and Trade system (CAB, 2017) and the 'fee and rebate' proposal in **Washington DC**, both of which are focused to some degree on revenue neutrality (Dysen, 2018).
Information and communication about the impacts	• The successful fossil fuel subsidy reform in **Iran** was carefully prepared by clear government communication through various channels, such as websites and hotlines to answer questions about the reform. The government also proactively consulted the private sector to discuss potential concerns about the policy reform (Atansah *et al.*, 2017). • The Government of **Malaysia** used multiple channels (including a public forum, YouTube and Twitter) to communicate fossil fuel subsidy reform in 2013 (Fay *et al.*, 2015).
Getting the timing and sequencing right	• Gradual fossil fuel subsidy reform in **Iran** helped with gaining public acceptance and reducing adverse effects (Rentschler and Bazilian, 2017b). • Sudden and drastic price increases, by contrast, may spark public protests, as was the case for subsidy reforms in **Bolivia** and **Nigeria** (Beaton *et al.*, 2013). • Subsidy reform in **Egypt** in 2014 was possible during the 'honeymoon period' of the new el-Sisi Government (Moerenhout, 2018).
Considering wording and framing	• The Government of **India** successfully framed its Direct Benefit Transfer for LPG scheme as a means of addressing inefficient service delivery (Jain *et al.*, 2018). • In the carbon pricing schemes in **Alberta** and **Switzerland**, carbon prices are labelled as 'levies' (FOEN, 2017; Government of Alberta, 2018).
Using revenues appropriately	See details and examples in table 6.2.

Table 6.2: Options for revenue recycling.

Recycling option	Objective(s)	Example(s)
Reduce income taxes	Growth, employment	• **Germany** (energy tax reform): A 1.7-percentage point reduction in compulsory public pension contributions increased employment by 0.6 percent (Bach *et al.*, 2002; Welsch and Ehrenheim, 2004). • **Sweden** (energy tax; carbon tax of €120): Revenues led to continued reductions of labour taxes; tax revenues comprise 1.6 percent of gross domestic product (GDP) and 3.6 percent of national tax revenues.
Cash transfers	Equity, popular support	• **British Columbia**, **Canada** (carbon tax of C$35 [€24] in 2018): up to C$135 [€92] per adult and C$40 [€27] per child in 2018. • **Alberta**, **Canada** (carbon levy of C$30 [€21] in 2018): tax rebate (on average C$135 [€92] per inhabitant in 2018, dependent on income and family status). • **Switzerland** (CO_2 levy of CHF96 [€85] in 2018): Majority of revenues recycled to citizens as a uniform transfer (CHF88 [€78] in 2018).
Investments, fostering structural change	Growth, equity, popular support	• **Alberta**, **Canada** (carbon levy of C$30 [€21] in 2018): Revenues spent on infrastructure, public transit and energy efficiency.
Affected industry support	Industry support, leakage avoidance, employment	• **Sweden** (energy tax; carbon and energy tax of €120): Lower tax rate for industry, but tax reduction phased out over time and abolished in 2018. • **Switzerland** (CO_2 levy of CHF96 [€85] in 2018): subsidy for employed workers.
Climate projects and low-carbon investment	Popular support, sustainability	• **Germany** (energy tax reform): support of renewable energy and housing sector. • **Switzerland** (CO_2 levy of CHF96 [€85] in 2018): One third of the revenues were allocated to helping reduce housing sector emissions and financing a low-carbon technology fund. • **British Columbia**, **Canada** (carbon tax of C$35 [€24] in 2018): Used to finance a Clean Energy Fund and provide investment support for emission reductions projects. • **India** (coal tax of INR400 [€5] per tonne of coal, approx. €2/tCO_2): Part of revenues used for clean energy and environment fund. • **Colombia** (carbon tax of US$5 [€4]): Revenues spent on environmental and natural conservation projects.

Note: Carbon prices are per metric tonne of CO_2.
Source: Own elaboration, based on information from ministries.

If revenues from carbon taxes are used to reduce other pre-existing taxes, such as income tax, the overall costs of carbon pricing are lower than if revenues are transferred lump-sum to firms or households (Goulder, 1995; Bovenberg, 1999). Detailed analyses that take into account the full range of existing tax distortions suggest that a green fiscal reform might even create economic gains (see, e.g., Parry and Bento, 2000; Parry *et al.*, 2014).[5] Such gains may also arise when countries harbour a large informal economy, prone to tax evasion. Energy taxation and environmental fiscal reform are particularly appealing in low- and middle-income countries where substantial informal economies make relying on corporate and personal income tax more difficult, and where administrative capacity is weak (Besley and Persson, 2014). In such countries, income taxes tend to encourage informal activities, so reducing income taxes and raising more revenue from energy taxes can increase economic efficiency (Bento *et al.*, 2018).

6.4 Addressing the broader fiscal policy framework: policy packages, coordination and alignment

The effectiveness of fiscal policies in the energy sector can be increased if other market failures and barriers are addressed by complementary policies. For example, capital markets, innovation and network externalities are typically larger for new and emerging technologies, including low-carbon technologies. As upfront capital costs are often higher for renewable than for fossil projects, low-carbon investment in developing countries is particularly affected by macroeconomic and policy risks (Waissbein *et al.*, 2013; Hirth and Steckel, 2016; Rodríguez-Manotas *et al.*, 2018). Technology support, innovation and de-risking policies can address these barriers and strengthen the environmental impact of carbon pricing (Kalkuhl *et al.*, 2012; Schmidt, 2014; Dressler *et al.*, 2018; see also Chapter 7).

Better alignment of broad tax policy can help reduce carbon emissions. Subsidies or tax deductions related to commuting (Su and DeSalvo, 2008), company cars (Harding, 2014) and the aviation sector (Gössling *et al.*, 2017) are common in many developed countries and tend to encourage carbon-intensive transport choices. Replacing property taxes with land value taxes can reduce urban sprawl and increase housing density, which in turn reduces the need for longer commutes (Banzhaf and Lavery, 2010).

Policy coordination extends across sectors. Increasing carbon prices in the energy sector can increase emissions from land-use change due to increased bioenergy production, if the associated emissions are not properly accounted for (Searchinger *et al.*, 2009; Haberl *et al.*, 2012). Consistent policies and price signals across sectors can significantly mitigate GHG emissions and help manage future risks associated with rising carbon prices (Golub *et al.*, 2017; 2018 and Lubowski and Piris-Cabezas, 2017). Fiscal policies such as ecological fiscal transfers, contingent on environmental performance, can also play a role in the land-use sector. They could be a way to implement REDD+[6] when international pay-for-performance or carbon market finance flows to the national or state government level (Loft *et al.*, 2016). There is growing experience with ecological fiscal transfers, including transfers of tax revenues to support protected areas and forests in Portugal (Santos *et al.*, 2012), several Brazilian states (May *et al.*, 2011) and India (Busch and Mukherjee, 2018). Land taxes on agricultural land can also help reduce agricultural land use and deforestation (Kalkuhl and Edenhofer, 2017).

6.5 Conclusion

This chapter provides two important insights. Firstly, while governments frequently use excise taxes on energy and fuels for raising public revenues, fiscal policy in most countries is currently not geared towards delivering the transition to a low-carbon economy. Core climate policies are not in place, existing carbon rates are too low and inconsistent, and broad fiscal systems are not well aligned with decarbonization. Secondly, this need not be the case. Increasing the costs of carbon-intensive energy to steer investment and behaviour towards low-carbon options and allocating carbon tax revenues to create a fiscal system that supports inclusive sustainable development are entirely within reach. Decisions on how to use revenue are critical to building public support and harnessing the full power of price-based policy to cut carbon emissions.

5 The first case, where costs of climate policy are reduced when revenues from carbon pricing are used to reduce pre-existing distortionary taxes, is called 'weak double dividend'. The second case, where climate policy creates economic gains through reduction of distortionary taxes, even when the environmental effects are not accounted for, is called 'strong double dividend'.

6 Reducing Emissions from Deforestation and Forest Degradation, as well as conservation, sustainable management of forests and enhancement of forest carbon stocks.

Chapter 7. Bridging the gap: The role of innovation policy and market creation

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7.1 Introduction

By pairing innovation in the use of existing technologies and in behaviour with new technologies, directed innovation has the potential to radically transform societies and reduce their greenhouse gas (GHG) emissions. Therefore, accelerating innovation is a key component of any attempt to close the emissions gap, but it will not happen by itself.

As innovation is inherently uncertain and often costly, it requires access to substantial amounts of finance as well as acceptance of inevitable failures and losses across the innovation landscape. This landscape covers everything from basic to applied research, and from demonstration to scale-up, deployment and diffusion, with feedback effects between the various stages, meaning that funding requirements can escalate quickly. Moreover, as there are often long lead times from the invention of a sophisticated GHG-saving process or material to its transformation into a commercial product and its diffusion through newly created markets, innovators require extraordinary patience.

Well-crafted innovation policy that kickstarts and steadies innovation across the landscape can make a significant contribution to closing the financing gap, and in this case the emissions gap. This means that the public sector must often lead in terms of taking risks through ambitious innovation policy. Such policy requires more considerations to co-create and shape markets than simply fixing market failures. In other words, the public sector plays a crucial role in directing the innovation process rather than just filling the gaps. In the past, direction has been shaped through a mission-oriented approach: framing and solving societal problems and using all available levers to crowd-in other sources (Mazzucato, 2017; 2018a). This includes sustaining and accelerating innovation, not just in research and development (R&D) but across the entire innovation landscape, such as by providing patient finance that risk-averse actors are not willing to provide. No other actor can replace the public sector.

This chapter explores the type of policies that can accelerate low-carbon innovation for closing the emissions gap, and barriers to implementing them. Section 7.2 discusses what we regard as the four policy principles to drive additional investment, while section 7.3 illustrates how these principles have been crucial to the success of solar photovoltaic (PV). Section 7.4 discusses barriers to implementing active policies, before section 7.5 concludes by highlighting challenges and opportunities for accelerating low-carbon innovation through policy.

7.2 Innovation policies

7.2.1 Risk-taking across the innovation landscape

Innovation policy requires attention to be paid to the entire innovation chain: from the supply side (from basic and applied R&D to demonstration) to the demand side (regulations, subsidies and taxes, procurement, and significant changes in consumption patterns) (Polzin, 2017; Mazzucato, Semieniuk and Watson, 2015). In low-carbon sectors, in addition to grant funding, an important share of research, development and venture capital funding comes from public sources (Mazzucato and Semieniuk, 2017) and almost half of the investments into demonstration projects originate in public innovation institutions (Nemet *et al.*, 2018). Similarly, governments are highly active on the demand side with subsidies — whether set administratively (such as feed-in tariffs) or through auctions — loan guarantees and significant direct investment (Mazzucato and Semieniuk, 2017). Public procurement can also help spur innovation by favouring low-carbon technologies (Edler and Georghiou, 2007, see also online appendix A.3) and regulation must be conducive to innovation, which includes avoiding over-regulation while new business models are still forming. Successful innovation is often accompanied by the public sector's lead on taking risks at all stages of the innovation chain.

Box 7.1 Electric vehicle innovation policy across the innovation chain in China

China's efforts to innovate in electric vehicles (EVs) are a clear example of a governmental attempt to coordinate both supply-side (push) and demand-side (pull) measures in order to achieve specific goals. Policies involve a combination of investments in R&D, the creation of multiple demonstration zones for the purposes of experimentation, policies to spur industrial development, deployment subsidies for manufacturers, favourable tax- and fee-based incentives for consumers, and the provision of necessary infrastructure.

China's supply-side policies started during its 8th five-year plan (1991–1995), when public R&D funds were first allocated to EV technology. This supply-side support has continued and increased, taking different forms during subsequent five-year plans (Zheng *et al.*, 2012; Hou *et al.*, 2012). Most recently, the Ministry of Science and Technology issued a National Key R&D Programme for EV for 2016–2018, which is the most influential public R&D programme in China. There has been continuous and strengthening complementary supply-side support.

Industrial policy for EVs lagged behind these early investments in R&D, largely because industrial policy dating from the first auto-industry policy in 1994 originally aimed to establish a domestically competitive conventional automobile industry through a joint-venture formation strategy (Gallagher, 2006). In 2009, however, there was a strategic move to the new-energy vehicle industry, which was listed as one of seven strategic emerging industries in 2010, and later as one of 10 key fields in the Made in China 2025 plan. A combination of policy instruments has been applied, including demonstration programmes, finance and taxation measures, and administrative regulations. An influential regulation was recently issued, under which vehicle manufacturers will face compulsory production targets for new-energy vehicles starting in April 2018. If they fail to meet the targets, they will either need to purchase credits from other manufacturers or pay a fine (Lu, 2018). The emphasis on new-energy vehicle is therefore becoming increasingly explicit in industrial policy.

Demand-side policies also commenced in 2009 with subsidies for the purchase of electric vehicles. In 2016, these subsidies were renewed for up to US$8,736 per electric vehicle, although they are scheduled to be phased out by 2020. Other purchase incentives include exemptions from purchase tax, travel tax and import tax for selected EV original equipment manufacturers. In some of the pilot cities, EVs are also exempt from the licence plate lottery system and the restricted land access applied to conventional vehicles (Harrysson *et al.*, 2015; Du and Ouyang, 2017). Moreover, EVs enjoy waived or reduced parking fees and highway tolls in some pilot cities (Gao *et al.*, 2015). The state government has also issued a series of policies and standards for the construction of charging infrastructure (aiming to build 12,000 charging stations by 2020) and many pilot cities also employ subsidies (Du and Ouyang, 2017; Lu, 2018).

Alongside these supporting policies, clear objectives for industry development and market creation have been set out. By 2020, EV production capacity (including plug-in hybrids) will reach two million, and EV stocks will exceed five million. Moreover, the fuel efficiency standard for average fuel consumption of all passenger cars produced in 2020 is set at 5 litres/100km, down from 6.65 litres/100km in 2015 (The State Council, 2012; Ministry of Industry and Information Technology, 2016).

With this constellation of policies rolled out from 1991, the Chinese Government has pushed and pulled electric vehicles into the marketplace. China's stock of EVs grew at an average rate of 69 percent between 2013 and 2017, and the country was home to almost 40 percent of the world's EVs in 2017.

Table 7.1: China's EV (including plug-in hybrid) stock from 2009 to 2017 (in thousands)

	2009	2010	2011	2012	2013	2014	2015	2016	2017
China	0.5	2	7	17	32	105	313	649	1228
World	7	14	61	179	381	704	1239	1982	3109
China's share	7%	14%	11%	9%	8%	15%	25%	33%	39%

Source: IEA, 2018b

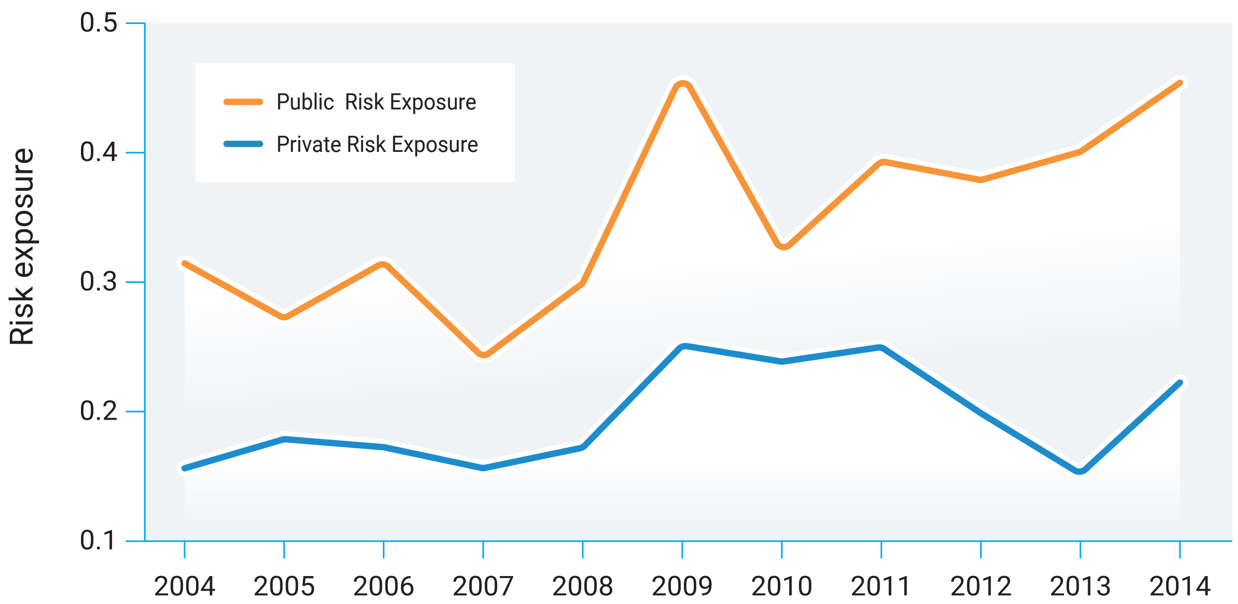
Policy coordination is as important as attention to the whole landscape. For example, procurement policies cannot work unless the demanded products have been developed and demonstrated, but the dependence runs both ways: feedback effects from deployment and diffusion stimulate new product development and enable cost reductions through learning by doing (Lundvall, 1992; Freeman, 1995; Gallagher *et al.*, 2012). This dependence also extends to consumer attitudes and their definition of the 'good life', with consumer demand for low-carbon products having the potential to drive innovation (Perez, 2017). By developing a coordinated policy that heeds these interdependencies, the public sector can not only fix market failures, but also create and shape markets for new innovative technologies (Mazzucato, 2018b).

7.2.2 Patient strategic finance

Innovation policy across the innovation chain is most effective when it involves patient finance for direct investments from public organizations placed strategically at all stages of the innovation process. Private investors often perceive new technologies as risky and are unwilling to provide capital at scale, especially given the long lead times (CPI 2013; Schmidt, 2014; Mazzucato and Semieniuk, 2017). However, innovation feeds off patient finance that is looking for long-term returns. As with any venture, such finance must also welcome risk and endure the failure of several projects (Mazzucato, 2018b). By being patient, such finance becomes strategic and supports innovation programmes until they reach their goal (Chan *et al.*, 2017). The high-risk, long-term and capital-intensive character of the demonstration and deployment stages of innovation makes public investment in this area key.

The growth of renewable energy markets illustrates the importance of public strategic finance. Financing the bulk of the US$120 trillion needed to steer the energy sector onto a low-carbon path by 2050 (IEA and IRENA, 2017) will require considerable public investments. Individual projects are often very capital-intensive; even early-stage demonstrations in energy and manufacturing sectors may require investments exceeding US$1 billion, while the pathway to profitability may take many years (Lester, 2014). Almost half of global investments in the renewable energy sector are now being financed by public agencies and state-controlled enterprises, as private financing has stagnated in absolute terms since around 2008.[1] Public money has been disproportionately directed to high-risk projects, mobilizing, or 'crowding in'[2], additional private business and leaving lower-risk technologies such as onshore wind mainly to private actors, as figure 7.1 illustrates (Mazzucato and Semieniuk, 2018).

Figure 7.1: Average relative risk exposure on a 0–1 scale of public and private investors in renewable energy assets 2004–2014 globally, excluding investments made in China.



Source: Mazzucato and Semieniuk (2018).

1 The public share of finance in directed historical energy transitions was often even higher (Semieniuk and Mazzucato, 2018).

2 Crowding in is a word play on the idea of debt-financed government spending replacing or 'crowding out' private investment. In innovative products, as this chapter shows, government finance (whether itself debt financed or not) may be necessary to mobilise private finance in the first place. (See also online appendix A.4 on state investment banks' crowding in of private investors).

One of the most important policy vehicles for strategic finance and 'crowding in' private investors are state investment banks (SIBs). Several national and subnational governments have founded green state investment banks (such as Australia's Clean Energy Finance Corporation) or mandated existing SIBs to support low-carbon technologies (such as the Brazilian Development Bank) (NRDC *et al.*, 2016; OECD, 2017). In addition, multilateral development banks (such as the World Bank) have pledged to green their portfolios (Steffen and Schmidt, 2017). Geddes *et al.* (2018) identify five functions through which these SIBs have been able to leverage private capital: the provision of capital, de-risking, awareness-raising among investors, market signalling (where an SIB's endorsement improves a technology's reputation) and by providing a crucial early-mover function. These functions are detailed in online appendix A.4.

Together, these five functions can help overcome private investors' initial aversion towards new technology and project types. The de-risking, signalling, and early-mover functions are particularly important for projects that contain non-incremental technological innovation. As SIBs take a financial position in such projects, they can also incur financial losses when a project fails. They therefore need performance criteria (such as portfolio benchmark return or leveraged private finance target) and a capital base that allows them to invest in higher risk immature technologies. Defining the risk exposure that a SIB can take is an important part of their mandate, and should be aligned with the overall ambition of innovation policy, as discussed next.

7.2.3 Directed portfolios

Innovation policy is most effective when it sets ambitious directions, rather than aiming to simply 'level the playing field'. Steering towards a low-carbon economy is one broad direction that involves additional choices as to which set of technologies should receive funding and how much. Unless the public sector sets such directions, private actors' choices will unintentionally create directions, which may be into high-carbon sectors (Wüstenhagen and Menichetti, 2012). Due to the long-lived nature of many assets created today, this carries the risk of locking the economy into a high-carbon path (Unruh, 2000). To avoid doing so, investments into low-carbon innovation must be directed boldly towards several strategically selected sectors within the low-carbon area (Mazzucato, 2017). This portfolio approach preserves multiple pathways, meaning that if one path fails, others are available and some will succeed (Schmidt *et al.*, 2016).

A number of developing countries have highly constrained national budgets that limit their ability to finance a policy portfolio that goes beyond immediate needs, such as national security, health care, education, other infrastructure, and energy access and security. Nevertheless, several funding mechanisms have the potential to boost countries' finance for innovative projects, such as the Green Climate Fund. This United Nations Framework Convention on Climate Change (UNFCCC) entity catalyses climate finance from both public and private sources to provide investment support to developing countries. Countries retain ownership of where the fund's resources are invested, as such investments are made in the context of their national climate strategies and plans. They can also use the UNFCCC's Technology Mechanism to help develop relevant strategies and technology investment portfolios. Another example, focused more on local business development, is the World Bank's Climate Innovation Centers (infoDev, 2018). Design lessons for these and similar mechanisms are available from the Global Fund in the area of public health (Sachs and Schmidt-Traub, 2017).

7.2.4 Mission-oriented innovation

One way to structure a complex set of policies is to conceive of innovation policy as targeted towards achieving a concrete 'mission'. Mission-oriented innovation policy defines an ambitious goal and then sets specific steps and milestones to achieve it (Foray *et al.*, 2012).[3] The mission requires public innovation organizations to set out tasks that mobilize various actors (business, non-profit, public) for bottom-up experimentation across different sectors (Mazzucato, 2017).

Lessons from past mission-oriented innovation policies suggest that cross-sectoral innovation is necessary to reach goals: for example, the US Apollo Mission required not just 'rocket science' but also innovation in the textile sector for the astronaut suits, for instance. In addition, the German Energiewende [Energy Transition] policy has required all sectors in Germany to transform themselves, such as the steel sector lowering energy consumption through repurpose, reuse and recycling strategies (European Commission, 2018). Meanwhile, in the USA the SunShot Initiative in PV (see section 7.3) has mobilized 347 organizations through grants in nine subprogrammes, covering actors from manufacturing firms to municipalities seeking innovative solutions to permitting, zoning and financing (DOE, 2018). Box 7.2 describes an international mission-driven initiative for accelerating innovation in advanced materials.

This section has outlined the key elements of an innovation policy framework for accelerating low-carbon innovation. One important takeaway from this discussion is that innovation policy itself can and must be innovative: different technologies and different areas of the innovation chain require different support mechanisms (Huenteler *et al.*, 2016). Accelerating innovation may therefore require entirely new approaches to innovation policy.

3 This differs from invention-oriented innovation policy, which focuses on R&D only, or system-oriented policy that seeks to provide a good system conducive to innovation, but does not set a direction (Edler and Fagerberg, 2017).

Box 7.2 The Clean Energy Materials Innovation Challenge — Mission Innovation

Advanced materials – with ever-increasing performance requirements – are the fundamental components of new energy technologies, ranging from non-toxic, high-density batteries and advanced power electronics to low-cost organic solar cells and electric cars (Chu *et al.*, 2016). Discovering and developing such materials much faster would accelerate the transition to a clean-energy future. The Clean Energy Materials Innovation Challenge is part of the larger Mission Innovation, launched at COP 21, which aims for a coalition of countries to accelerate the energy innovation needed for a low-carbon future.

The challenge aims to bring the rate of innovation in materials discovery closer to that in computing power, the 'Moore's Law' of materials discovery. The goal is to combine three cutting-edge technologies (artificial intelligence, robotics, and computing) with materials sciences to accelerate the discovery of advanced materials by at least a factor of 10, from around 20 years to under two years and, eventually, a matter of months.

Mission Innovation launched the Materials Challenge in September 2016 with limited funding from the co-leading countries: Mexico and the United States of America, later joined by Canada.[4] Funding was used to gather leading scientists in academia and business, thought-leaders, government representatives, NGOs and civil society observers from 18 countries for a four-day Basic Research Needs (BRN) workshop to identify the fundamental research needs, challenges and opportunities, and define the path forward. The workshop developed the concept of an integrated Materials Acceleration Platform (Aspuru-Guzik *et al.*, 2018), an autonomous or self-driving laboratory with smart robots that are able to rapidly design, perform and interpret experiments in the quest for new high-performance, low-cost and clean-energy materials (Tabor *et al.*, 2018).

In May 2018, Canada and Mexico funded two international collaborative demonstration projects of US$10 million each. Additional countries are launching similar projects in collaboration with this Innovation Challenge, including India, South Korea, European Union members, and even non-Mission Innovation countries such as Singapore. As such, it is a test-bed for increased intergovernmental cooperation in mission-oriented innovation policy and effective public private partnerships.

7.3 Solar photovoltaic innovation

Innovation in solar photovoltaic (PV) technology illustrates both the nonlinear nature of innovation and how the various innovation policies reviewed above drive and shape it. PV was deployed with a compound annual growth rate of about 38 percent between 1998 and 2015 (Creutzig *et al.*, 2017), continually exceeding forecasts (see figure 7.2a). PV diffusion spurred cost reductions through 'learning by doing', scale economies and R&D, but also lowered profit margins through increasing competition (Nemet, 2006; Carvalho *et al.*, 2017), which in turn stimulated further deployment of ever-cheaper systems. However, PV innovation preceded diffusion by several decades, driving down costs dramatically. From 1975 to 2016, PV module prices fell by about 99.5 percent (figure 7.2b), and every doubling of installed capacity coincided with a 20 percent drop in costs (Kavlak *et al.*, 2017). Public innovation policies were — and continue to be — crucial for this process throughout the innovation chain.

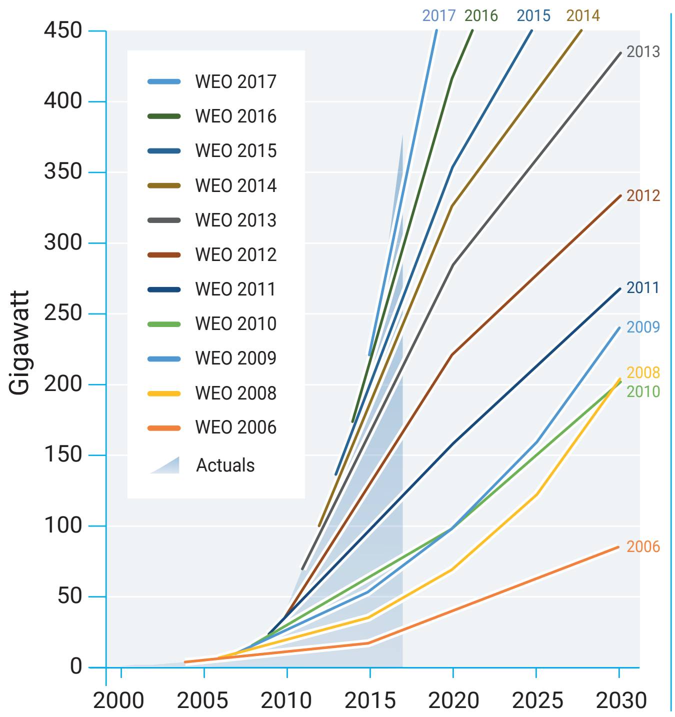
Governments often act as lead risk-takers. For example, the Sunshine Project launched by the Japanese Ministry of International Trade and Industry in 1974 (IEA, 2016) made Japan an early leader in PV manufacturing and deployment (Trancik *et al.*, 2015). As for the US, the first silicon PV cell was demonstrated by researchers at Bell Telephone Labs in 1954, which benefited from large contracts with US government agencies (Chapin *et al.*, 1954). Subsequently, the US government agencies NASA and the Advanced Research Projects Agency developed PV for satellite use (Perlin, 2002). As a result of the 1973 oil crisis, new policies were enacted and research on PV expanded in the laboratories of the newly founded US Department of Energy (DoE) (Ruegg and Thomas, 2011).

Government-funded innovation continues to this day. In a mission-oriented policy approach, the DoE launched the SunShot Initiative in 2011 with the concrete goal of reducing the cost of US solar energy systems – including the costs of installation, permitting and financing – by 75 percent to a levelized cost of US$0.06/kWh by 2020. As SunShot supported innovation that met this goal in 2017 (three years earlier than expected), the target has been revised to US$0.03/kWh by 2030 (Chu *et al.*, 2016).

In 1990, the German parliament enacted the first PV feed-in tariff, which guaranteed the sale of all PV-generated electricity substantially above market price. The feed-in tariff subsequently became a major law, setting a direction for innovation in Germany and effectively creating a PV market. In fact, the feed-in tariff is credited with drawing many producers into the market, thereby pushing Germany to become a global leader in solar installations (Trancik *et al.*, 2015). This built on long-standing collaborations between German PV companies and a network of public research institutes (Jacobssen and Lauber, 2006), while the German SIB,

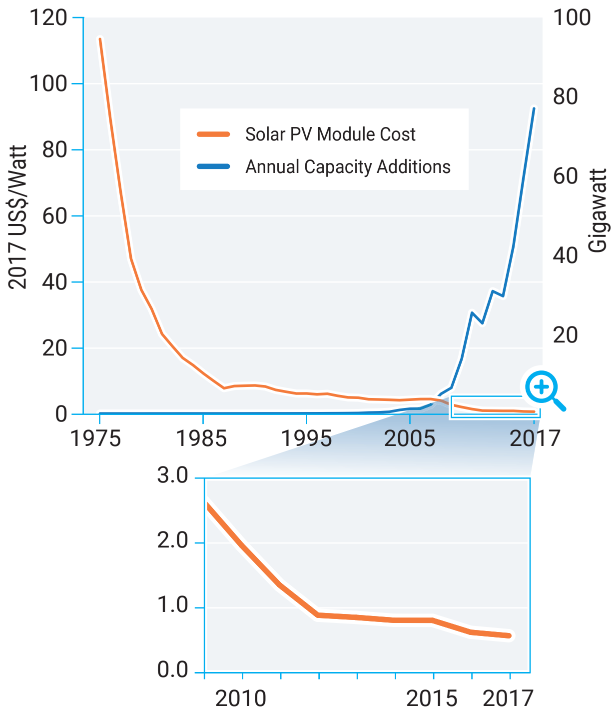
4 Eighteen of the 24 Mission Innovation members participate in this initiative. The Materials Innovation Challenge international workshop and activities have been funded by Mexico's Energy Innovation Funds, managed by the Ministry of Energy of Mexico (SENER), the US Department of Energy (DOE), Natural Resources Canada (NRCAN), and the Canadian Institute for Advanced Research (CIFAR).

Figure 7.2a: Cumulative solar PV installations compared to forecasts from various IEA World Energy Outlooks (WEO).



Source: Updated from ClimateWorks *et al.* (2015).

Figure 7.2b: Historical price reductions and annual installations, 1975–2017.



Sources: Earth Policy Institute (2018) and Barbose *et al.* (2018, Fig. 13) for prices, Earth Policy Institute and IRENA (2018) for capacity.

KfW, boosted German renewable energy deployment by providing strategic finance in the form of concessional loans in 2009. In that year, Germany almost doubled its cumulative PV capacity to 10 GW and 41 percent of all projects benefited from KfW loans (Bickel and Kelm, 2010). The next three years saw unprecedented growth in German PV capacity, which slowed only when the feed-in tariff was reduced in 2012.

The baton of PV leadership then passed to China, whose companies have been manufacturing more than half of global PV cells every year since 2011 (Zhang and Gallagher, 2016). In the 2000s, Chinese manufacturers benefited from the generous demand-pull policies in richer countries (especially in Germany, Italy, Spain and the US), while transferring technology and vertically integrating production processes in China and benefiting from financial support from local governments (Zhang and Gallagher, 2016). In 2011, a feed-in tariff created a major market for PV also within China itself, while the Chinese SIB, China Development Bank, disbursed generous credit lines to Chinese manufacturers (Quitzow, 2015).

Against the backdrop of this comprehensive network of policies across the innovation landscape, solar PV is now nearing cost-competitiveness with electricity from fossil fuels and is being deployed around the world. The story of PV innovation is an international one: from the USA and Japan to Germany and then China and increasingly other countries. Yet, what is a success today looked less certain and faced many obstacles in the early stages, revealing the importance of public policies for PV innovation and market creation along the lines examined in the previous section. The next section discusses some common barriers to implementing innovation policy.

7.4 Barriers to implementing innovation policy

7.4.1 Organizational aims and mandates

The above-mentioned innovation policies recognize the institutions that plan and carry out the various polices as being key to their success. Unlike most public organizations and their fear of failure, the US energy innovation agency (ARPA-E) measures its success by how many risks it is willing to take and the impact of its successes (Mazzucato and Penna, 2015a). Nevertheless, most public organisations are risk averse, so it is important to learn from the US energy innovation agency's (ARPA-E) approach in terms of paying attention to the internal capabilities of public institutions: their willingness to set bold missions and nurture organizational capacity and experimentation, and their ability to evaluate themselves in dynamic ways, rather than by static cost-benefit analysis (Kattel and

Mazzucato, 2018). Staying abreast of how innovation is changing markets also requires these institutions to deliberately engage with a wider set of actors and to track and quickly learn from wider innovation progress (Shakya and Byrnes, 2017). Emboldening agencies and institutions is easier when they are kept apart from political decision makers and thus independent of the short-term political process (Haley, 2016).

Setting strong policy mandates also helps strengthen an institution's capabilities. For instance, for SIBs to effectively address the low-carbon finance gap, their mandate needs to define their sectoral and geographical focus areas, specify the instruments to be used, define 'green' safeguards for project selection, and determine the SIB's own financing. Given the high importance of in-house technological capabilities and the resources needed to build them, the sectoral focus areas must be aligned with the government's mission-oriented low-carbon policy (Mazzucato and Penna, 2016). It is also important that the instruments that a SIB provides are appropriate for their target sectors and project types. For instance, projects with very long loan tenors require long-running loan guarantees. Importantly, these instruments should also be designed in a way that reflects the financial sector's existing structures. One example is household rooftop solar projects in Germany: the KfW channelled loans through Germany's local banks, utilizing Germany's decentralized financial sector (Hall *et al.*, 2016). Depending on the sectors and the scale, governments must also decide whether SIBs can refinance themselves in capital markets, as KfW has done (Mazzucato and Penna, 2015b) and, if so, whether they can utilize a state guarantee.

7.4.2 Funding

Many countries have significant barriers to financing innovative technologies because, on top of the technology being unproven, the countries themselves are considered high-risk places to invest, with high political risk, policy uncertainty and currency fluctuation (Schmidt 2014; BNEF *et al.*, 2016), now exacerbated by an increased exposure of these countries to climate change risks (Buhr *et al.*, 2018). This situation makes both international and domestic investors averse to exposing themselves to additional risk by investing in new technologies and business models without a solid track record (Mehta *et al.*, 2017; Kidney *et al.*, 2017). Most of the poorest countries are also small markets with a large proportion of low-income consumers who lack credit history, which limits potential investors' interest in engaging with the government to improve investment conditions (GOGLA *et al.*, 2017). In addition to these challenges, matching the right type and scale of finance to the opportunities in innovative small-scale distributed technologies has significant transaction costs, as well as the risk of the business models around these technologies having a limited track record (Hystra, 2013; Lewis *et al.*, 2017).

To stimulate innovation in low-carbon sectors, such as distributed energy, several developing countries have set up platforms that aggregate finance for small-scale renewable energy projects, thereby reducing transaction costs to public and private investors and managing risk (Shakya and Byrnes, 2017). Various types of aggregation platforms have successfully reduced the cost of capital to the energy enterprises by bundling the enterprises' small ticket deals or their assets into portfolios that diversify risk across several projects, and standardizing project data to build investors' confidence. This bundling has also allowed the platforms to meet the deal size preferred by larger-scale investors offering cheaper finance (Wilson *et al.*, 2014). In addition, the platforms create a space for dialogue among public policymakers, entrepreneurs and private investors to resolve market challenges (Bertha Centre and WWF, 2016; Simanis, 2012). Once again, it is important to recognize that as not all sources of finance are the same, those with an appetite for risk should be sought out (Mazzucato and Semieniuk, 2018). Financing constraints are also prevalent in developed countries, especially at the municipal level, and the online appendix A.3 explores innovative financing mechanisms to overcome these constraints for low-carbon lighting.

Large amounts of funding are by themselves insufficient, as funding needs to be stable over time. Cyclical spending is problematic on both the supply and demand sides. On the supply side, fluctuations in spending due to political decisions (or the expectation that spending will not be stable) can hinder investments in long-term projects (Chan *et al.*, 2017), whereas on the demand side, the business cycle is an important consideration. While the financial crisis of 2008 led to various 'green stimuli', this increased spending was often soon replaced by austerity measures. Perhaps the most dramatic casualty of tightened fiscal belts was the Spanish support for renewable energy. Until 2008, Spain's feed-in tariff supported one of the fastest expansions of not-yet-commercialized renewable energy. However, the feed-in tariff was paid by the central government and added to its fiscal deficit, so when Spain was hard-pressed to tighten the budget, it was reduced retroactively. Spanish renewable energy investment dropped after 2008 and collapsed completely after 2012 (Mir-Artigues *et al.*, 2018), contributing to a crisis in Spanish PV manufacturing companies (Ibarloza *et al.*, 2018). Ringfencing support policies across the business cycle is therefore crucial for long-lead-time innovation processes.

7.4.3 International competition

Countries' domestic policies are also affected by the industrial policy aspect of innovations. Developed countries fear that their expensive R&D efforts will be appropriated by other, poorer countries that take a large market share due to lower production costs. The most prominent case is perhaps the migration of the PV manufacturing industry to China, reviewed above. 'Free-riding' on others' efforts, whether perceived or real, is prevalent in the literature analysing how countries contribute to global climate change mitigation efforts (Barrett, 2007). The flipside of this fear is the concern of developing countries — which are almost completely excluded from the current corporate R&D activities (Nolan, 2018) — that they will remain excluded from a new, green technological revolution. They see themselves at risk of having to buy the new technology from developed countries, without benefiting economically from the transition to a low-carbon economy, and at risk of 'premature deindustrialization' (Rodrik, 2016). Overcoming these differences touches on some of the most controversial aspects of the global political economy, but may be critical for effective innovation policies around the world.

7.5 Conclusion: opportunities and challenges

Creating markets and shaping innovation policy is crucial to bringing about the technologies needed to close the emissions gap. Public sector institutions can take the lead thanks to their unique ability to take risk and be patient and strategic from a societal rather than strictly financial point of view. Equal attention must be given to the supply and demand sides, with feedback loops key to allowing diffusion patterns to feed into innovation patterns. Common success factors include specialist organizations coordinating activities across the innovation chain, patient and strategic finance that leverages other actors, and setting directions while sustaining a portfolio of innovation processes in that direction. A mission-oriented approach to policy can open the innovation process up to a large number of participants.

International collaboration has the potential to unlock additional innovation capacity through leveraging greater pools of money and talent and providing an avenue for international best-practice-sharing. Mission Innovation and its sister organization, the Clean Energy Ministerial, which exists to accelerate technology diffusion, have the potential to play such a role. Other international initiatives have also set ambitious targets, such as the pledge by tropical nations under the International Solar Alliance to help each other mobilize US$1 trillion for solar energy deployment. They can be even more effective when they join with powerful private international initiatives, such as the Breakthrough Energy Coalition, which is committed to funding clean-energy innovation.

Challenges remain, however. Sustaining portfolios of technologies is expensive and identifying which investments to prioritize is challenging, as the innovation landscape alters so quickly during this unprecedented and rapid transition. Innovation organizations must also constantly innovate themselves in order to match realities with policies, while competing for talent with private sector employers. Developing countries face an uphill battle in competing with better-funded competitors from developed countries; furthermore, finding niches that are both emissions-mitigating and revenue-generating is as uncertain as innovation itself. The new international initiatives have great potential but they also face problems inherent in international cooperation. Governments are inclined to cooperate but less willing to send funds across borders, and the same is true of private actors sharing data and insights when they participate in these initiatives (Cherry *et al.*, 2018). Even if innovation is successfully accelerated, the world must still grapple with unintended consequences like the rebound effect where, in the case of energy-saving innovations, part of energy saved per unit of the innovative product is brought back through an increased consumption of the now more efficient, and hence cheaper product or consumption of other energy-intensive products with the money saved on the innovative product (Sorrell 2008; Gillingham *et al.*, 2016).

Public institutions carry a large responsibility for innovation, but in an era of tight budgets, committing the necessary finance is difficult. Organizations leveraging private initiatives need to continue learning and improving. Meanwhile, other issues such as financial market regulation favouring low-carbon portfolios would be a useful complement (Campiglio *et al.*, 2018). Ultimately, however, the policies rely on confident and stable enough public institutions with good governance that can survive short-term economic and funding fluctuations. If they are willing to learn from mistakes while staying confident of their key contribution, they could help dramatically lower GHG emissions over and above current policies.

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Chapter 1 – Introduction

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Chapter 2 – Trends and progress towards the Cancun pledges, NDC targets and peaking of emissions

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Chapter 3 – The emissions gap

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Chapter 7 – Bridging the gap: The role of innovation policy and market creation

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Bridging the gap: Sectors and topics covered in the UN Environment Emissions Gap Reports

In addition to assessing the emissions gap, the Emissions Gap Reports cover opportunities for bridging the gap. Previous reports have demonstrated how proven policies and measures, if scaled up across countries and regions in terms of ambition, stringency and geographical reach can contribute to bridging the emissions gap, while supporting broader development goals. A summary of key areas and sectors covered in previous reports is provided here.

Previous Emissions Gap Reports are available at http://www.unenvironment.org/emissionsgap.

The Emissions Gap Report 2017

Sectoral greenhouse gas emission reduction potentials in 2030

- Assessment of emission reduction options and GHG mitigation potentials in the agriculture, building, energy, forestry, industry and transport sector.
- Evaluates the potentials for these options to bridge the emissions gap and compares the bottom up analysis with results from Integrated Assessment Models.

Phasing out coal

- Assessment of the role of phasing out coal for achievement of the Paris Agreement goal.
- Provides an overview of incentives that can facilitate and incentivize a smooth transition, including portfolios of market, non-market based and complementary instruments such as carbon prices, improved support to grid infrastructures and storage facilities, and de-risking clean investment for financial institutions and governments.
- Assesses policies for managing impacts on workers, coal owners, industry and energy users such as wage subsidies, compensatory subsidies, and redistributive policies.

The role of short-lived climate pollutants

- Synthesizes findings regarding the GHG emission reduction potential of methane, tropospheric ozone, black carbon and hydrofluorocarbons (HFCs), as well as sulphur dioxide and organic carbon.
- Assesses the technical potential of measures available via proven technologies in the exploration and distribution of coal, oil and gas, and in the waste sector.

Carbon dioxide removal

- Provides an overview and assessment of natural (biological) options for carbon dioxide removal options such as afforestation, reforestation and soil carbon sequestration.
- Provides an overview and assessment of technological engineering carbon dioxide removal options such as direct air capture, bioenergy combined with carbon dioxide capture and storage (BECCS), Ocean Alkalinity Enhancement and CO_2 to Durable Carbon.

The Emissions Gap Report 2016

The role of energy efficiency

- Assesses energy efficiency policies in the building, industry, and transport sectors and the co-benefits that these can provide for governments, businesses and households.
- Considers GHG emissions reductions opportunities through systems thinking and integration, circular and sharing economy as well as advances in information and communication technology.

Sustainable Development Goals and climate change mitigation

- Considers the interaction between Sustainable Development Goals (SDGs) and climate change mitigation objectives and identifies areas of synergies and potential trade-offs between different goals and associated targets.
- Outlines key elements of an integrated approach to the realization of the Sustainable Development Goals (SDGs) in the context of climate change to minimize trade-offs and maximize synergies between different objectives.

The Emissions Gap Report 2015

International Cooperative Initiatives

- Assessment of the quantitative impact of international cooperative initiatives on GHGs emission reductions in various different sectors, and of the role of non-state actors and the UNFCCC process.
- Provides an overview of private sector engagement in GHG mitigation efforts and summarizes key issues for improved monitoring, reporting and verification of these initiatives.

Forest-related activities

- Provides an assessment of the total technical mitigation potential of reducing forest degradation by: Preventing selective logging, fire/drought, fuelwood harvest, and peatlands fire while enhancing forest management, and; enhancing carbon sequestration through reforestation, 'wide-scale' restoration of closed-canopy forest and mosaic restoration.
- Assess the economic and technical mitigation potential of forest-related mitigation options such as expansion of protected areas, supply chain interventions, positive incentives for landholders and exogenous economic factors such as falling commodity prices.
- Considers the REDD+ mechanism's role as a cost-effective instrument to realizing forest-based emission reductions from deforestation.

The Emissions Gap Report 2014

Sustainable development and addressing climate change

- Provides an overview of the interface between sustainable development and climate change mitigation priorities and illustrates areas where these priorities can be mutually reinforcing and deliver multiple benefits for human development and wellbeing.
- Assesses international collaborations supporting the sustainable development goals and barriers to attain them.

Energy efficiency

- Assesses the potential GHG emission reductions and multiple economic and social benefits that can be realized through energy efficiency measures in: buildings, appliances and lighting, industry, transport, and electricity production, transmission and distribution.

The Emissions Gap Report 2013

International Cooperative Initiatives

- Considers the success factors of global dialogues, formal multilateral processes and implementation initiatives focusing on their goals; participation criteria; funding mechanisms; incentives and benefits; and transparency and accountability measures.

Agriculture:

- Provides an overview of the potential mitigation contributions from sustainable agricultural practices such as no-tillage practices by direct seeding under the mulch layer of the previous season's crop, as well as improving nutrient and water management in rice production, preventing GHG emissions from soil disturbances and fossil-fuel use by farm machinery.

The Emissions Gap Report 2012

Building sector:

- Evaluates the GHG mitigation potentials and the economic and social co-benefits of improved building codes, appliance standards and labels, designed to increase energy efficiency.

Transport sector:

- Evaluates the GHG mitigation potentials and the economic and social co-benefits of transit-oriented development, bus rapid transit, and vehicle performance standards for new light-duty vehicles.

Deforestation:

- Analyzes a set economic instruments and policies as well as command-and-control measures used separately and in combination to scale-up the protection of forest areas and address the drivers of deforestation.

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